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INTRODUCTION.

During the summer of 1913 the Secretary of Agriculture established a board to reorganize the system of publications of the Department of Agriculture. In accordance with the proceedings of the board and the suggestions from representatives of the Weather Bureau, the "Bulletin of the Mount Weather Observatory" ceased to be published with the completion of its volume 6. Any subsequent contributions from the members of the research staff that would have been proper for that Bulletin will be incorporated in the Monthly Weather Review. The climatological service of the Weather Bureau will be maintained in all its essential features, but its publications, so far as they relate to purely local conditions, will be incorporated in the monthly reports for the respective States, Territories, and colonies.

Beginning with January, 1914, the material for the Monthly Weather Review will be prepared and classified in accordance with the following sections:

Section 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

Section 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

Section 3.—*Forecasts and general conditions of the atmosphere.*

Section 4.—*Rivers and floods.*

Section 5.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

Section 6.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto.

In general, appropriate officials will prepare the six sections above enumerated; but all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.

The voluminous tables of data and text relative to local climatological conditions that have during recent years been prepared by the 12 respective "district editors" will be omitted from the Monthly Weather Review, but will in future be collected and published by States at selected section centers.

The data needed in Section 6 can only be collected and prepared several weeks after the close of the month whose name appears on the title page; hence the Review as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are especially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Central Meteorological and Magnetic Observatory of Mexico.
The Director General of Mexican Telegraphs.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, St. Petersburg.
The Philippine Weather Bureau.
The General Superintendent United States Life-Saving Service.

SECTION I.—AEROLOGY.

FREE-AIR DATA IN SOUTHERN CALIFORNIA, JULY AND AUGUST, 1913.

By the Aerial Section—WM. R. BLAIR in Charge.

[Dated, Mount Weather, Va., May 26, 1914.]

The Astrophysical Observatory, of the Smithsonian Institution, and the Mount Weather Observatory of the Weather Bureau cooperating during July and August, 1913, made observations in southern California: (*a*) Of solar radiation at high levels, by means of a photographically recording pyrheliometer, carried by free balloons; (*b*) of the total moisture content of the air above Mount Wilson, by means of the spectroscope; (*c*) of nocturnal radiation, by means of the K. Ångström compensation apparatus; (*d*) of the meteorological elements, air pressure, temperature, humidity and movement, at different altitudes by means of meteorographs, carried by free balloons at Avalon, and by captive balloons at Lone Pine and at the summit of Mount Whitney. The pyrheliometric observations have already been discussed by C. G. Abbot in Science, March 6, 1914. It is the purpose of this present paper to communicate more particularly the meteorological observations.

(*a*) THE FREE BALLOON OBSERVATIONS.

Morning and evening ascensions were made on July 23 and 24, 1914, and thereafter daily ascensions until August 12, 1914—23 ascensions in all. When a pyrheliometer was taken up, in addition to the meteorograph, the ascension for the day was so timed that the highest point would be reached about noon. On other days the ascensions were made shortly after sunrise or just before sunset. Table 1 shows the number of balloons recovered, their landing points, and other information of general interest.

TABLE 1.—*Statistics of sounding balloon flights from Avalon, Cal., during July and August, 1913.*

Date.	Hour.	Balloons. Number.	Balloons. Ascensional force.	Landing point.	Horizontal distance traveled.	Direction traveled.	Highest altitude reached.	Lowest temperature recorded.
1913			*Kg.*		*Km.*		*M.*	*°C.*
July 23	6:06 a....	2	......	Huntington Beach, Cal.	42	ne.	25,160	−56.0
24	5:13 p....	2	0.8	Armada, Cal.........	122	ene.	20,389	−55.8
26	5:11 p....	2	0.8	San Diego, Cal.......	131	ese.	....	....
27	4:57 p....	2	0.9	Oceanside, Cal.......	91	e.	23,870	−64.7
28	5:05 p....	2	1.1	Chino, Cal...........	97	ne.	19,485	−62.6
29	11:10 a...	2	1.2	Los Angeles, Cal.....	80	n.	23,066	−60.4
30	10:54 a...	2	1.0	Atmore's Ranch, Cal.	140	nnw.	32,643	−53.9
31	10:37 a...	2	1.6	Los Pasos Hills, Cal..	122	nnw.	22,294	−58.9
Aug. 1	10:36 a...	2	1.4	New Hall, Cal.......	128	n.	23,466	−58.6
2	10:59 a...	2	1.3	Inglewood, Cal......	72	n.	21,302	−67.3
3	5:07 p ...	2	0.9	Downey, Cal	70	n.	17,428	−67.5
5	5:07 p....	2	0.8	Fullerton, Cal.......	75	nne.	....	....
7	4:52 p....	2	0.8	Colton, Cal	120	ne.	6,442	−25.2
8	5:23 p....	2	0.9	Baldwin Park, Cal ..	97	nne.	14,100	−43.9
10	4:43 p....	2	0.9	Pacific Ocean........	4	nw.	1,976	19.3

All free balloons were started at Avalon, Santa Catalina Island, Cal. Because of the possibility of the instrument coming down in the ocean, balloons were sent up in pairs and with a float. This float weighed approximately 450 grams. Each balloon was filled until it would lift decidedly everything to be sent up except the float. The balloons were then attached to the system in such a way that when either of them burst it would detach itself from the system, which then sank to the earth's surface with the remaining balloon. This device by which the balloons are connected with the system and which serves the purpose of releasing the burst balloon is shown in figure 1. It is made of spring brass wire of approximately 2.4 mm. diameter. The pressure of the springs B and C on the wire A at the points D and E is sufficient to prevent the rings from slipping off in case cord F or G becomes slack. The weight of the burst balloon or of what is left of it slips the ring off easily. Cords F and G must be so short that they will not twist above the device.

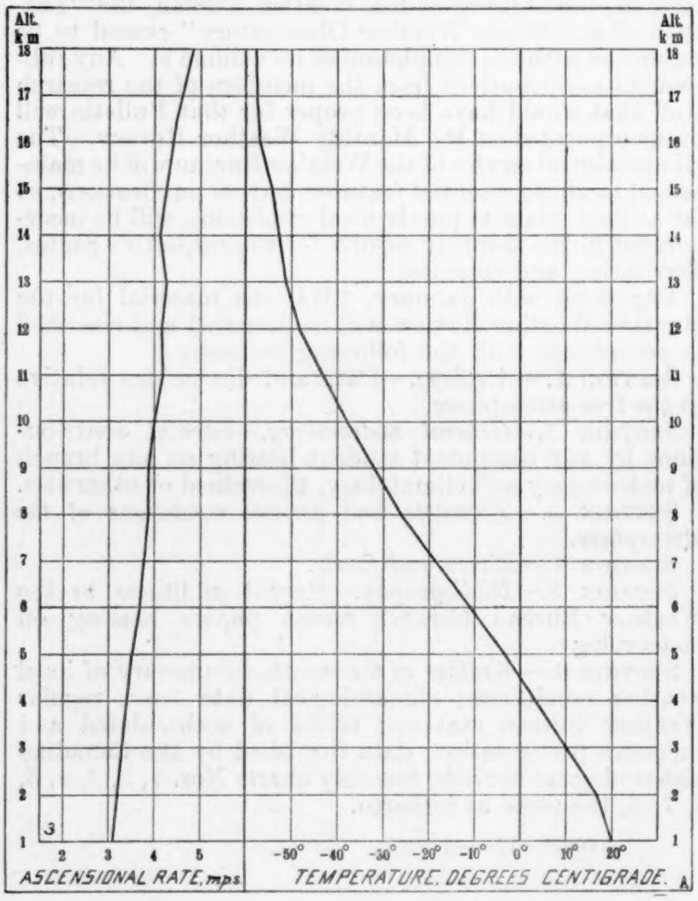

FIG. 3.—Relation between ascensional rates of balloons and air temperatures.

The balloons used were of thick rubber, similar to those used at Huron in the early autumn of 1910 and at Fort Omaha in the late winter of 1911 but not so large. They were filled with electrolytic hydrogen which had been compressed in steel cylinders.

The highest ascension of the series was made on July 30. This exceeds the previous highest ascension from this continent by more than two kilometers. The record obtained in this ascension is shown in figure 2.

In seven of the ascensions from which records were returned the instrument was carried to an altitude of 18 or more kilometers above sea level. The temperatures recorded and the ascensional rates of the balloons have been averaged and compared in Table 2 and in figure 3.

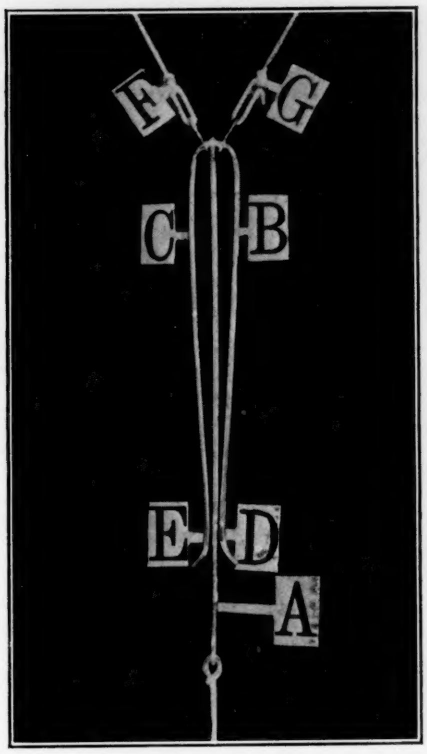

FIG. 1.—Device for releasing burst balloon.

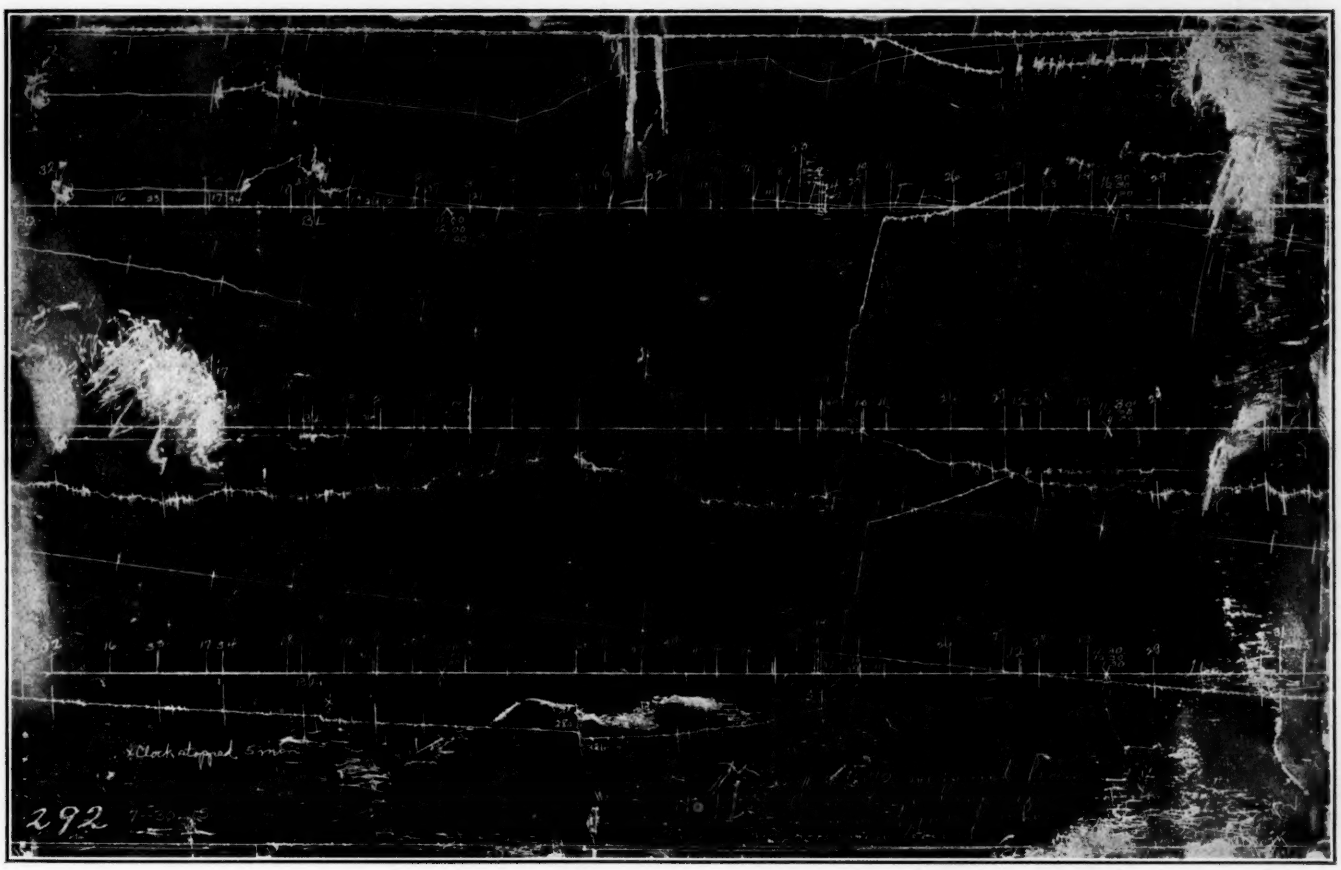

FIG. 2.—Record obtained in sounding balloon ascension of July 30, 1913.

TABLE 2.—*Temperatures recorded at different altitudes and ascensional rates of balloons for sounding balloon ascensions at Avalon, Cal., July and August, 1913.*

Altitude above surface.	July 23.		July 24.		July 27.		July 30.		July 31.		Aug. 1.		Aug. 3.		Means.		Altitude above surface.
	Rate of ascent.	Temperature.	Rate of ascent.	Temperature.	Rate of ascent.	Temperature.	Rate of ascent.	Temperature.	Rate of ascent.	Temperature.	Rate of ascent.	Temperature.	Rate of ascent.	Temperature.	Rate of ascent.	Temperature.	
Km.	*M.p.s.*	°*C.*	*M.p.s.*	°*C.*	*M.p.s.*	°*C.*	*M.p.s.*	°*C.*	*M.p.s.*	°*C.*	*M.p.s.*	°*C.*	*M.p.s.*	°*C.*	*M.p.s.*	°*C.*	*Km.*
1	4.02	18.5	3.14	14.6	3.33	13.3	1.58	18.2	3.97	21.6	2.78	24.2	2.90	30.0	3.10	20.1	1
2	4.17	12.6	3.33	14.7	3.27	9.6	1.55	20.3	4.17	18.7	2.90	18.3	3.03	21.8	3.20	16.6	2
3	4.44	5.5	3.51	8.1	3.27	2.5	1.63	18.5	4.27	12.8	3.03	10.9	3.06	14.6	3.32	10.4	3
4	4.63	−1.0	3.58	2.4	3.27	−4.7	1.81	11.0	4.33	5.8	3.17	3.6	3.09	7.3	3.41	3.5	4
5	4.76	−7.9	3.51	−2.8	3.33	−13.3	2.12	3.8	4.44	−1.5	3.40	−1.6	3.09	−0.5	3.52	−3.4	5
6	4.90	−14.7	3.51	−9.3	3.44	−20.5	2.42	−3.5	4.76	−11.3	3.51	−9.5	3.21	−8.2	3.68	−11.0	6
7	4.90	−21.6	3.51	−16.3	3.40	−29.0	2.67	−9.8	5.21	−20.6	3.62	−17.5	3.27	−17.0	3.80	−18.8	7
8	4.90	−29.1	3.33	−20.8	3.40	−38.4	2.92	−15.9	5.46	−28.6	3.79	−23.5	3.27	−24.5	3.87	−25.8	8
9	4.83	−34.3	3.21	−26.3	3.40	−45.1	3.12	−22.8	5.65	−34.6	3.92	−30.0	3.12	−31.1	3.89	−32.0	9
10	4.90	−38.8	3.12	−31.7	3.33	−50.2	3.44	−30.2	5.95	−42.2	4.12	−36.6	3.14	−36.8	4.00	−38.1	10
11	5.56	−41.4	2.95	−38.2	3.30	−53.8	3.70	−37.3	6.41	−47.4	4.12	−43.2	3.33	−42.7	4.20	−43.4	11
12	5.13	−43.4	2.95	−42.4	3.37	−57.4	3.83	−44.2	6.41	−52.3	4.12	−49.4	3.33	−49.2	4.16	−48.3	12
13	5.56	−46.5	3.06	−45.5	3.37	−57.5	3.88	−49.1	6.54	−56.9	4.17	−52.3	3.37	−50.1	4.28	−51.1	13
14	4.07	−50.6	3.21	−46.6	3.44	−58.7	4.02	−51.3	6.67	−56.7	4.12	−49.8	3.37	−54.0	4.13	−52.5	14
15	4.17	−54.8	3.37	−49.6	3.88	−61.5	4.33	−49.2	6.67	−55.4	4.12	−50.5	3.37	−59.2	4.27	−54.3	15
16	4.63	−55.8	3.55	−52.2	4.57	−62.2	4.57	−50.3	6.80	−57.7	3.88	−54.0	3.33	−65.3	4.46	−56.8	16
17	5.38	−56.6	3.74	−55.4	3.70	−63.0	4.90	−49.8	6.94	−58.6	4.22	−56.0	3.51	−62.3	4.63	−57.4	17
18	6.29	−56.7	3.33	−55.6	3.47	−60.8	5.13	−53.0	7.58	−58.0	4.83	−58.0	3.51	−62.0	4.88	−57.7	18

The mean of the observed temperatures in the seven ascensions does not show a minimum of temperature below the 18-kilometer level. The mean of the ascensional rates of the balloons shows, in general, an increase with altitude. Above the 18-kilometer level the individual ascensions show a decrease in the ascensional rates of the balloons soon after the minimum of temperature has been passed through. This relation between the air temperature and the ascensional rate of the balloons is similar to that already found. (See Bull. Mount Weather Observatory, Washington, 1911, **4**: 186.) It indicates that, in addition to the known factors entering into the ascensional rate of any balloon, there is the unknown factor of the difference in temperature between the gas in the balloon and the air through which the balloon is passing. While the temperature distribution in the free air is in general known, it would be impossible to predict, with sufficient accuracy for a particular ascension, the point of maximum ascensional rate or minor variations in the rate. On the other hand, careful observation of the ascensional rate of a free, sealed, rubber balloon might indicate fairly well the peculiarities of the temperature distribution at the time of the ascension. In this connection the author calls attention to an entirely erroneous statement in Bulletin of the Mount Weather Observatory, **4**:186, regarding the adiabatic cooling of hydrogen gas. The approximate rate of cooling per kilometer came in some way to be considered the rate to the 15-kilometer level. The statement based on this error should not have appeared, nor is it needed to account for the observed peculiarities in the ascensional rate of free rubber balloons under consideration.

The instruments used were the same as those used in previous series of soundings. The calibration of the instruments was similar to that for previous series, except that the pressure and temperature elements were calibrated in a smaller chamber in which ventilation and temperature were under somewhat better control and in which temperatures down to −60° C. could easily be obtained. (See Bulletin Mount Weather Observatory, Washington, 1911, **4**:187.)

The data obtained in each ascension are presented in Table 4 with interpolations at the 500-meter intervals up to 5 kilometers above sea level, and at 1-kilometer intervals above the 5-kilometer level. In figure 4 a diagram of the temperature-altitude relation is shown for each observation. Figure 5 shows the mean value of this relation for the period. The free air isotherms for the period are shown in figure 6. The horizontal projections of the balloon paths, as far as they could be observed, are shown in figure 7. Only one theodolite was used, the altitudes being computed from the observed air pressures.

An inversion of temperature, with the maximum temperature somewhere between the ½- and 2-kilometer levels, is shown in each curve of figure 4. This inversion of temperature is found, whether the observation be made in the morning, near noon, or in the late afternoon. It does not seem to accompany any particular wind direction. A similar inversion of temperature was observed in most of the ascensions made at Indianapolis, Fort Omaha, and Huron.

As shown in figure 5, the altitude at which the mean temperature for the period is a minimum is 17 kilometers. The minimum temperature observed in any ascension may be more than a kilometer above or below the height of this mean. In two ascensions, those of the 23d and 27th of July, the change of temperature with altitude begins to decrease at about the 8-kilometer level, while in the ascensions of August 2 and 3 this change does not take place until the 12-kilometer level. The temperature change from day to day is best shown in figure 6. The lowest temperature observed, −67.5°C., was at about the 16.5 kilometer level on August 3. About the same temperature had been observed at the 16-kilometer level on the day before.

A comparison of the curve shown in figure 5 with that shown in the Bulletin of the Mount Weather Observatory, **4**: 302, figure 31, shows the surface temperature indicated in figure 5 higher by 6.4°C., the minimum temperature lower by 3.5°C., the maximum next above this minimum less than 2°C. lower than the corresponding values shown in figure 31. The minimum temperature shown in figure 5 occurs at an altitude higher by 1.5 kilometers than that shown in figure 31. The maximum temperature next above the minimum temperature is shown at about the same altitude in both curves. The curves have the same general appearance. That shown in figure 5 represents summer conditions at latitude 33° N. That shown in figure 31 represents conditions in all seasons, to some extent; the late summer and early autumn being better represented than the other seasons, at about latitute 40° N.

The variations of humidity with altitude and from day to day are rather closely related to the variations of temperature. In Table 3 the absolute humidities observed have been assembled and a mean shown.

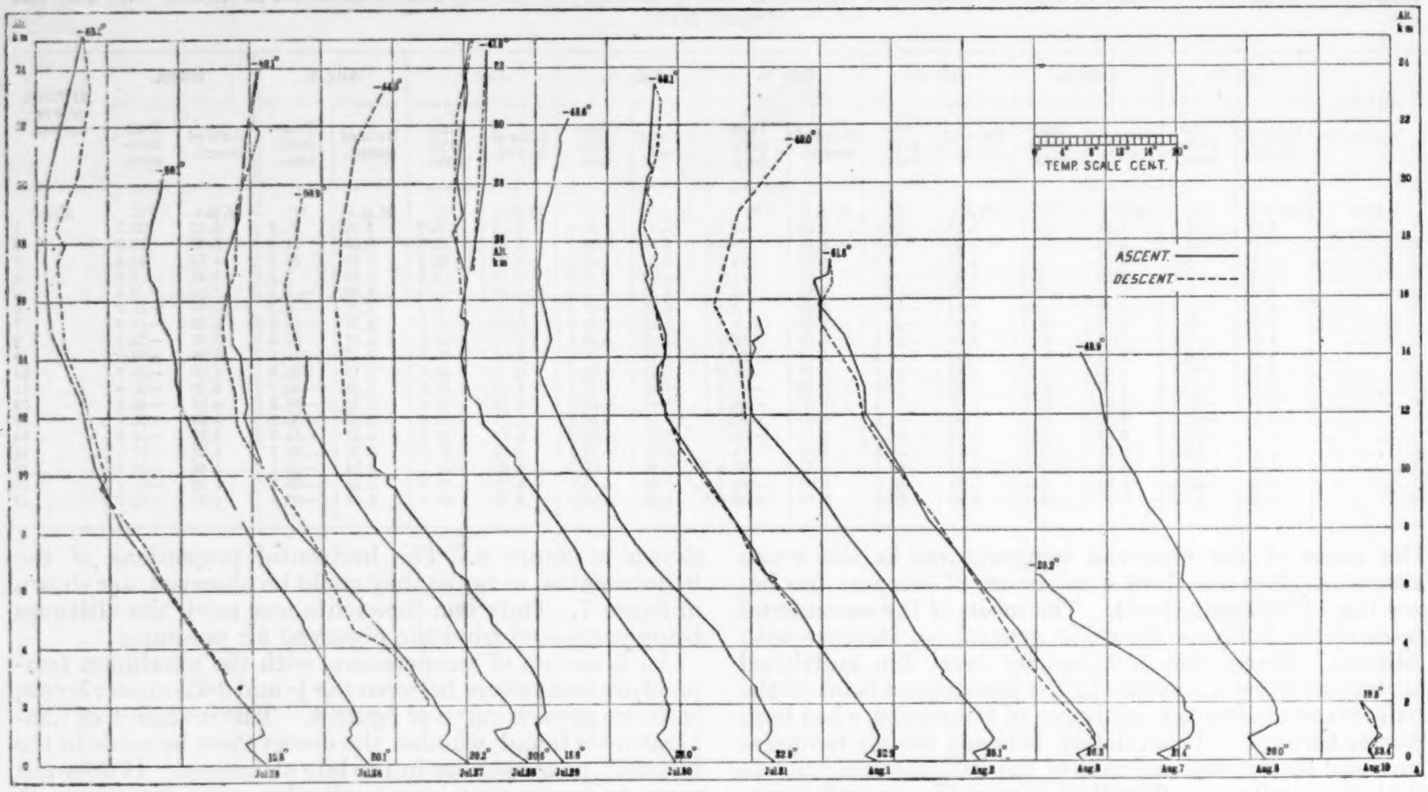

Fig. 4.—Vertical temperature gradients at Avalon, Cal., July 23–August 10, 1913.

Table 3.—*Absolute humidity (grams per cubic meter) at various levels on different dates, Avalon, Cal., 1913.*

Date.	Altitude (meters).																		
	34	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000.	6,000.	7,000.	8,000.	9,000.	10,000.	11,000.	12,000.	13,000.
1913.																			
July 23	12.651	10.109	9.248	6.942	5.597	4.495	3.354	2.291	1.608	1.106	0.793	0.415	0.207	0.095	0.055	0.034	0.024	0.019	0.013
24	11.363	9.740	8.808	7.562	4.993	3.871	2.976	2.329	1.820	1.441	1.162	....	....	....	....	....	0.035	0.023	0.016
27	11.949	9.687	8.708	7.288	5.003	2.852	1.661	1.301	1.064	0.839	0.581	0.289	0.118	0.040	0.017	0.009	0.006	0.003	0.003
28	10.813	8.755	7.980	5.330	3.642	2.985	2.429	1.480	1.015	0.698	0.516	0.272	0.125	0.051	0.023	0.010	0.005	0.003	0.003
29	9.933	9.372	8.913	7.645	4.711	3.056	1.964	1.163	0.674	0.384	0.265	0.112	0.060	0.019	0.011	0.006	0.002	....	....
30	12.415	11.913	10.625	6.418	5.922	4.108	2.351	1.381	0.993	0.780	0.687	0.330	0.219	0.103	0.048	0.020	0.010	0.004	0.003
31	12.952	11.261	8.640	4.717	2.379	1.434	1.444	1.210	0.855	0.580	0.344	0.193	0.118	0.062	0.034	0.014	0.007	0.004	0.002
Aug. 1	15.210	12.077	9.369	8.072	6.661	5.459	4.739	4.268	3.367	2.302	1.662	0.831	0.406	0.199	0.103	0.054	0.026	0.013	0.009
2	15.817	13.928	7.750	5.828	5.657	5.255	3.986	2.781	1.840	1.243	0.922	0.476	0.235	0.105	0.055	0.021	0.008	0.003	0.003
3	15.199	12.914	4.205	2.925	2.850	2.541	2.109	1.560	1.178	0.898	....	....	....	....	....	....	....	....	....
7	14.482	13.979	6.274	2.631	1.521	1.256	1.353	1.300	1.065	1.299	1.362	0.432	....	....	....	....	....	....	....
8	12.838	11.342	11.336	9.476	7.983	6.572	5.055	3.961	3.278	2.806	2.368	1.623	1.180	0.655	0.346	0.215	0.124	0.077	0.055
10	12.077	9.937	4.654	3.106	2.421	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Means	12.900	11.086	8.193	5.995	4.565	3.657	2.785	2.085	1.563	1.198	0.969	0.497	0.296	0.148	0.077	0.043	0.025	0.017	0.012

Date.	Altitude (meters).																		
	14,000	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	26,000	27,000	28,000	29,000	30,000	31,000	32,000
1913.																			
July 23	0.008	0.004	0.004	0.003	0.003	0.004	0.004	0.006	0.007	0.010	0.014	0.018	....	....	....	....	....	....	....
24	0.013	0.010	0.007	0.004	0.004	0.006	0.008	....	....	....	....	....	....	....	....	....	....	....	....
27	0.003	0.002	0.001	0.001	0.002	0.003	0.003	0.003	0.004	0.005	0.007	....	....	....	....	....	....	....	....
28	0.003	0.001	0.001	0.001	0.002	0.002	....	....	....	....	....	....	....	....	....	....	....	....	....
30	0.002	0.003	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.003	0.004	0.004	0.005	0.005	0.005	0.006	0.006
31	0.002	0.003	0.002	0.001	0.002	0.002	0.003	0.004	0.005	....	....	....	....	....	....	....	....	....	....
Aug. 1	0.012	0.011	0.007	0.005	0.004	0.004	0.006	0.006	0.007	0.008	....	....	....	....	....	....	....	....	....
2	0.003	0.004	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
8	0.033	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Means	0.009	0.005	0.003	0.002	0.003	0.003	0.004	0.004	0.005	0.006	0.008	0.010	0.004	0.004	0.005	0.005	0.005	0.006	0.006

The distribution of pressure at the earth's surface changes but little in type, and that never abruptly, during the period of observation nor does the pressure itself vary much from day to day. Figures 7 and 8 show the pressure distribution in a general way for the whole period. The positions of the centers of high and low pressure at 8 a. m. or 8 p. m., seventy-fifth meridian time, are shown by the circles, in which dates are also indicated. In the case of high pressure, these circles are connected by solid lines; in the case of low pressure, by dashed lines.

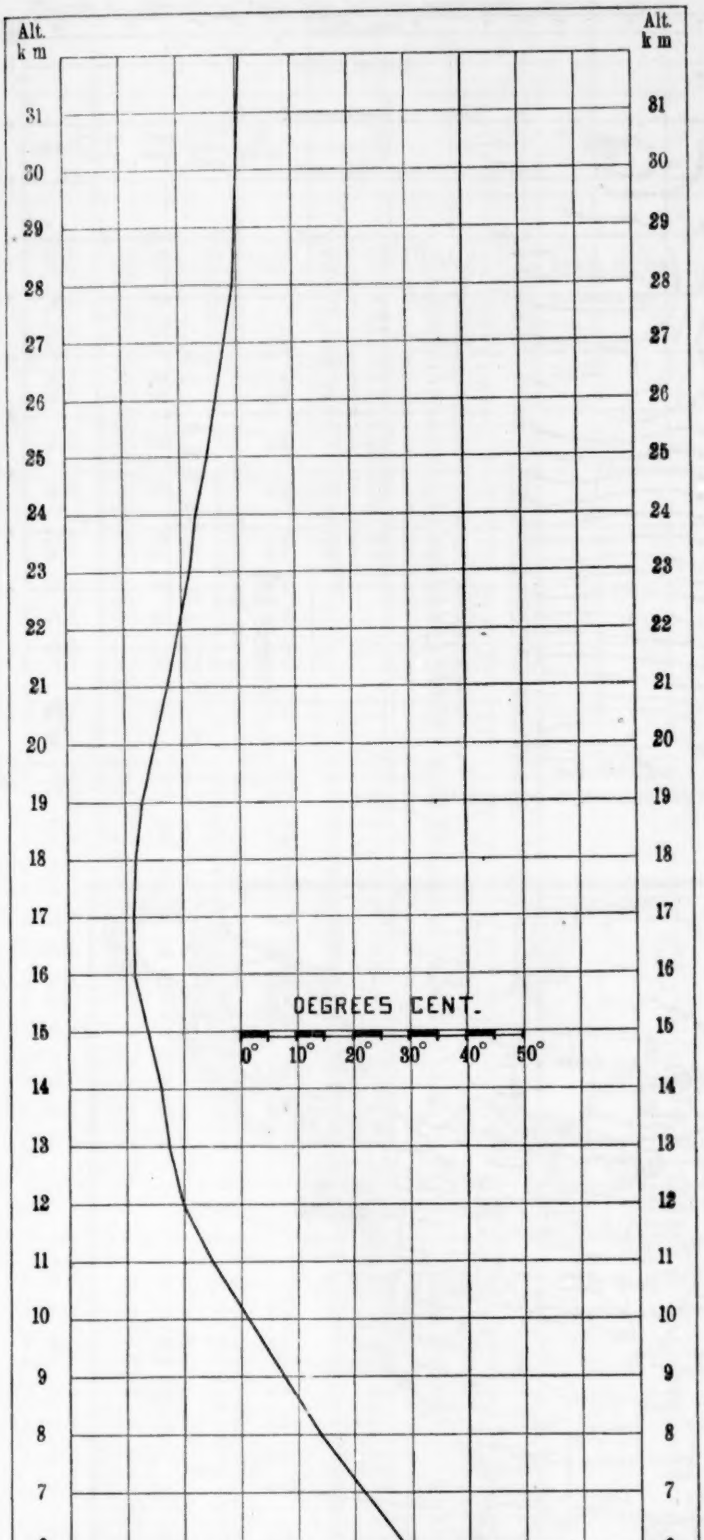

FIG. 5.—Curve showing mean temperature gradient at Avalon, Cal., July 23-August 3, 1913.

In three of the ascensions July 24 and 27 and August 3, the balloons were followed with the theodolite beyond the altitude at which the minimum temperature was recorded (see fig. 9). In another, August 2, the air movement could be observed up to 17 kilometers. On July 24 and 27 the winds were westerly, with a small south component up to the height at which the minimum temperature was found. Above this height the wind was easterly. On August 2 and 3 the winds were southerly, with a small west component up to the point of minimum temperature. Here again the winds became easterly. On July 24 the wind velocity increased as the easterly component made its appearance; on July 27 there was little change; on August 2 and 3 there was a decided decrease in velocity as the wind became easterly.

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*

JULY 23, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt 100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
A. M. h. m.	M.	Mm.	°C.		P. ct.	g./m³.		M.p.s.	
6 06.0	34	759.5	19.3	......	77	12.651	....	......	10/10 S. NNW.
6 08.0	489	719.8	14.3	1.1	83	10.111	N. 48° W..	1.1	
....	500	......	14.1	......	84	10.109	N. 47° W..	1.1	
6 09.1	737	699.0	12.4	0.8	92	9.972	N. 17° W..	1.0	In base of clouds. Inversion.
....	1,000	......	18.5	......	59	9.248	....	......	
6 10.2	1,032	675.0	18.9	−2.2	57	9.147	....	......	
6 12.2	1,454	642.3	17.1	0.4	49	7.068	....	......	
....	1,500	......	16.8	......	49	6.942	....	......	
....	2,000	......	12.6	......	51	5.597	....	......	
....	2,500	......	8.5	......	53	4.465	....	......	
6 17.4	2,784	547.5	6.3	0.8	54	3.975	....	......	
....	3,000	......	5.5	......	48	3.354	....	......	
6 18.9	3,194	520.8	4.9	0.3	43	2.883	....	......	
....	3,500	......	2.5	......	40	2.291	....	......	
....	4,000	......	− 1.0	......	36	1.608	....	......	
....	4,500	......	− 4.6	......	33	1.106	....	......	
6 24.5	4,719	430.1	− 6.1	0.7	31	0.919	....	......	
6 24.8	4,818	424.7	− 6.6	0.5	31	0.882	....	......	
....	5,000	......	− 7.9	......	31	0.793	....	......	
....	6,000	......	−14.7	......	29	0.415	....	......	
6 31.7	6,793	327.9	−20.0	0.7	27	0.241	....	......	
....	7,000	......	−21.6	......	27	0.207	....	......	
....	8,000	......	−29.1	......	25	0.095	....	......	
6 36.4	8,184	271.4	−30.5	0.8	25	0.082	....	......	
....	9,000	......	−34.3	......	25	0.055	....	......	
....	10,000	......	−38.8	......	25	0.034	....	......	
6 42.9	10,289	200.9	−39.9	0.4	25	0.030	....	......	
....	11,000	......	−41.4	......	24	0.024	....	......	
....	12,000	......	−43.4	......	23	0.019	....	......	
6 50.4	12,584	143.9	−44.6	0.2	22	0.016	....	......	
....	13,000	......	−46.5	......	22	0.013	....	......	
....	14,000	......	−50.6	......	21	0.008	....	......	
....	15,000	......	−54.8	......	20	0.004	....	......	
7 00.4	15,092	98.6	−55.2	0.2	20	0.004	....	......	
....	16,000	......	−55.8	......	20	0.004	....	......	
....	17,000	......	−56.6	......	20	0.003	....	......	
7 08.3	17,379	69.2	−56.9	0.1	20	0.003	....	......	Inversion.
....	18,000	......	−56.7	......	20	0.003	....	......	
....	19,000	......	−56.4	......	21	0.004	....	......	
7 15.1	19,983	46.1	−56.1	0.0	21	0.004	....	......	
....	20,000	......	−56.1	......	21	0.004	....	......	
....	21,000	......	−53.6	......	22	0.006	....	......	
....	22,000	......	−51.2	......	22	0.007	....	......	
....	23,000	......	−48.7	......	22	0.010	....	......	
....	24,000	......	−46.3	......	23	0.014	....	......	
....	25,000	......	−43.8	......	23	0.018	....	......	
7 26.8	25,160	21.5	−43.4	−0.1	23	0.019	....	......	
....	25,000	......	−43.0	......	23	0.020	....	......	
....	24,000	......	−42.1	......	21	0.020	....	......	
7 34.0	23,045	30.1	−41.1	−0.1	20	0.021	....	......	
....	23,000	......	−41.2	......	20	0.021	....	......	
....	22,000	......	−42.6	......	19	0.017	....	......	
....	21,000	......	−44.2	......	18	0.013	....	......	
7 43.9	20,314	45.0	−45.1	−0.4	17	0.011	....	......	
....	20,000	......	−46.4	......	17	0.010	....	......	
....	19,000	......	−50.5	......	17	0.00[illegible]	....	......	
7 51.5	18,411	60.0	−52.8	0.5	17	0.005	....	......	Inversion.
....	18,000	......	−50.7	......	18	0.006	....	......	
7 54.2	17,857	65.3	−50.0	−0.3	18	0.007	....	......	
7 57.7	17,254	71.7	−52.1	0.1	18	0.005	....	......	Inversion.
....	17,000	......	−51.8	......	18	0.006	....	......	
....	16,000	......	−51.1	......	19	0.006	....	......	
....	15,000	......	−50.4	......	19	0.007	....	......	
8 10.9	14,285	112.3	−49.8	0.4	20	0.008	....	......	
....	14,000	......	−48.6	......	20	0.009	....	......	
....	13,000	......	−44.5	......	21	0.015	....	......	
8 18.3	12,603	144.3	−43.0	0.3	21	0.018	....	......	
....	12,000	......	−41.5	......	21	0.021	....	......	
....	11,000	......	−38.8	......	22	0.030	....	......	
....	10,000	......	−36.4	......	23	0.041	....	......	
8 31.8	9,855	214.8	−36.0	−0.5	23	0.042	....	......	
8 33.7	9,536	224.9	−37.7	0.8	23	0.035	....	......	Inversion.
....	9,000	......	−33.5	......	23	0.055	....	......	
8 37.9	8,667	254.2	−31.0	0.8	23	0.071	....	......	
....	8,000	......	−25.8	......	25	0.129	....	......	
8 44.3	7,456	300.3	−21.6	0.5	27	0.207	....	......	
....	7,000	......	−19.4	......	28	0.265	....	......	
8 50.0	6,384	346.9	−16.4	0.6	29	0.359	....	......	
....	6,000	......	−13.8	......	30	0.464	....	......	
8 56.9	5,038	413.0	− 7.7	0.7	32	0.832	....	......	
....	5,000	......	− 7.4	......	32	0.852	....	......	
....	4,500	......	− 4.0	......	32	1.126	....	......	
....	4,000	......	− 0.7	......	32	1.464	....	......	
9 02.3	3,794	483.6	0.6	......	32	1.612	....	......	

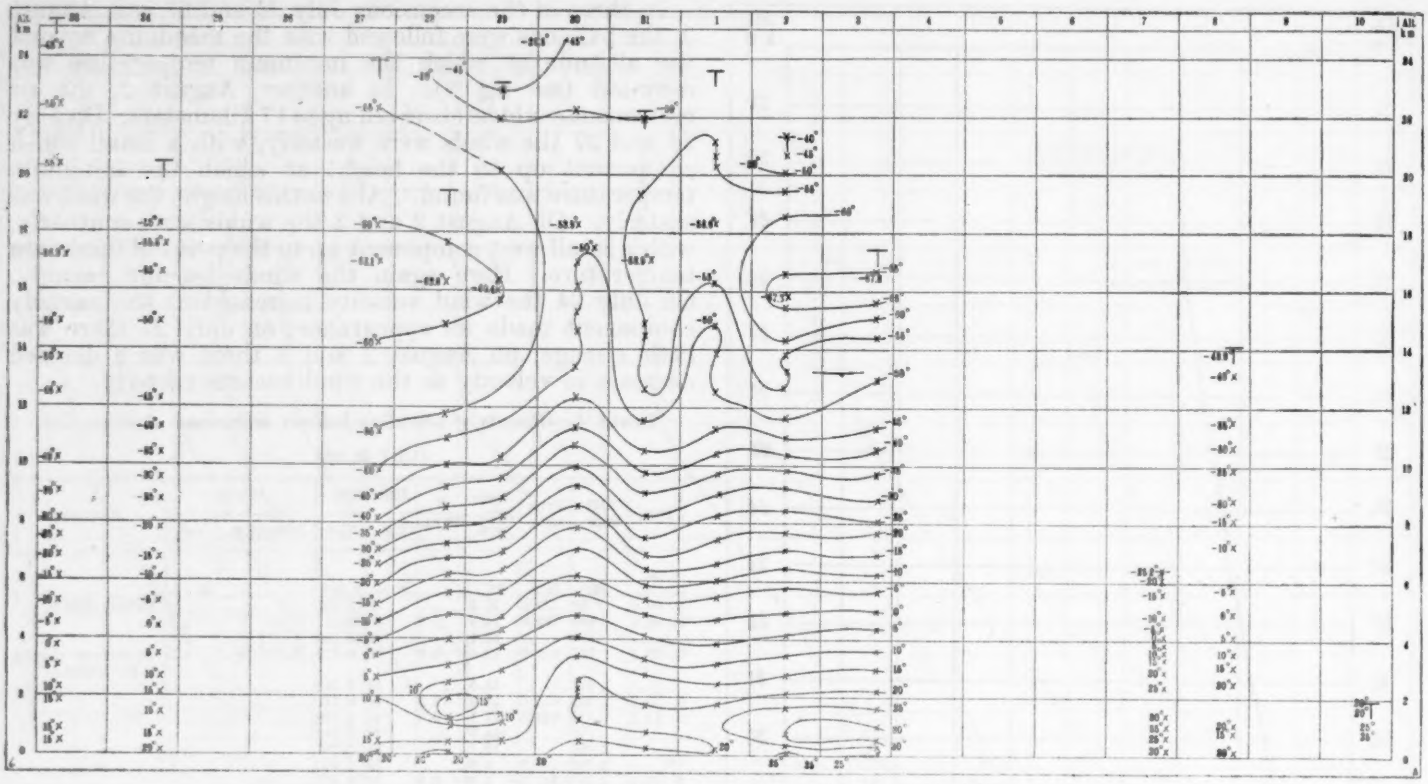

FIG. 6.—Free-air temperatures at Avalon, Cal., July 23–August 10, 1913.

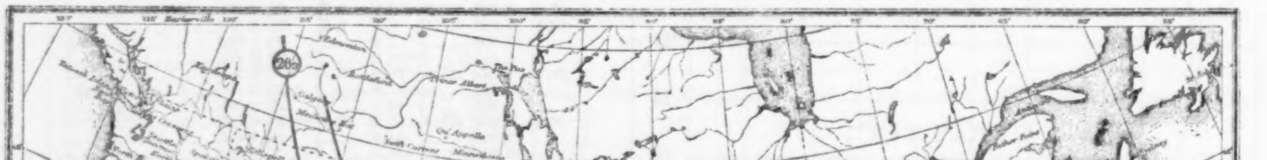

FIG. 7.—Pressure distribution in the western United States, July 22–28, 1913.

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Continued.

JULY 24, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt / 100 m.	Humidity.		Wind.		Remarks.
					Rel.	Abs.	Direction.	Vel.	
A. M. h. m.	M.	Mm.	°C.		P. ct.	g./m³.		M.p.s.	
5 13.8	34	759.7	20.1	......	66	11.363	SW......	5.9	
5 15.0	290	737.3	17.7	0.9	69	10.315	S. 26° W..	5.9	Few S. Cu. SW.
....	500	......	15.8	......	73	9.740	S. 49° W..	4.8	
5 18.1	858	689.3	13.0	0.8	79	8.887	N. 83° W..	3.1	Inversion.
....	1,000	......	14.6	......	71	8.808	S. 68° W..	2.5	
5 18.8	1,005	677.4	14.6	−1.1	70	8.684	S. 67° W..	2.4	
5 20.1	1,220	660.3	13.7	0.4	63	7.398	S. 76° W..	1.3	Inversion.
....	1,500	......	16.3	......	55	7.562	S. 31° W..	6.2	
5 21.3	1,507	638.1	16.4	−0.9	55	7.608	S. 30° W..	6.4	
5 23.9	1,925	607.5	15.1	0.3	41	5.243	S. 29° W..	7.6	
....	2,000	......	14.7	......	40	4.993	S. 29° W..	8.0	
....	2,500	......	11.4	......	38	3.871	S. 25° W..	10.0	
5 29.0	2,984	534.9	8.3	0.6	36	3.015	S. 22° W..	11.9	
....	3,000	......	8.1	......	36	2.976	S. 22° W..	12.0	
....	3,500	......	5.2	......	34	2.329	S. 37° W..	12.8	
5 33.5	3,907	477.8	2.8	0.6	32	1.870	S. 49° W..	13.4	
....	4,000	......	2.4	......	32	1.820	S. 49° W..	13.6	
....	4,500	......	− 0.5	......	31	1.441	S. 48° W..	14.3	
5 37.8	4,759	429.8	− 1.9	0.6	30	1.249	S. 48° W..	14.7	
5 38.3	4,853	424.7	− 1.9	0.0	30	1.249	S. 41° W..	21.7	
....	5,000	......	− 2.8	......	30	1.162	S. 44° W..	21.2	
5 42.1	5,588	386.9	− 6.2	0.6	29	0.852	S. 58° W..	18.9	
....	6,000	......	− 9.3	......	......	......	S. 58° W..	18.2	
5 48.2	6,968	323.4	−16.3	0.7	......	......	S. 58° W..	16.7	
....	7,000	......	−16.3	......	......	......	S. 60° W..	13.6	
5 48.8	7,114	317.0	−16.3	0.0	......	......	S. 66° W..	4.0	
5 53.1	7,999	281.8	−20.8	0.5	......	......	S. 62° W..	25.3	
....	8,000	......	−20.8	......	......	......	S. 62° W..	25.3	
....	9,000	......	−26.3	......	......	......	S. 63° W..	24.2	
5 58.5	9,171	240.2	−27.3	0.6	......	......	S. 63° W..	24.0	
....	10,000	......	−31.7	......	......	......	S. 72° W..	24.4	
6 05.2	10,423	201.6	−34.0	0.5	......	......	S. 77° W..	24.6	
....	11,000	......	−38.2	......	24	0.035	S. 72° W..	23.6	
6 08.9	11,016	185.3	−38.3	0.7	24	0.034	S. 72° W..	23.5	Few S. Cu. SW.
6 15.1	11,894	163.5	−41.8	0.4	25	0.024	S. 70° W..	19.2	
....	12,000	......	−42.4	......	25	0.023	S. 73° W..	18.7	
6 18.3	12,464	150.3	−45.1	0.6	24	0.016	S. 84° W..	16.4	
6 20.0	12,902	140.7	−45.1	0.0	24	0.016	S. 63° W..	22.2	
....	13,000	......	−45.5	......	24	0.016	S. 63° W..	20.4	
6 21.6	13,206	134.5	−46.1	0.3	24	0.014	S. 63° W..	16.1	
6 24.0	13,711	124.9	−46.0	0.0	23	0.014	S. 63° W..	18.2	
....	14,000	......	−46.6	......	23	0.013	S. 59° W..	18.4	
6 28.7	14,716	107.6	−47.9	0.2	23	0.012	S. 47° W..	18.8	
....	15,000	......	−49.6	......	23	0.010	S. 54° W..	15.7	
6 32.8	15,297	98.5	−51.3	0.6	23	0.008	S. 61° W..	12.3	
....	16,000	......	−52.2	......	23	0.007	S. 48° W..	13.2	
6 36.6	16,453	82.3	−52.8	0.1	23	0.006	S. 39° W..	13.9	
6 38.7	16,795	78.3	−55.1	0.7	22	0.005	S. 57° W..	1.7	
....	17,000	......	−55.4	......	22	0.004	S. 40° W..	3.2	
6 42.4	17,763	67.6	−55.8	0.1	22	0.004	S. 22° E...	9.0	Inversion.
....	18,000	......	−55.6	......	22	0.004	S. 74° E...	6.3	
6 45.2	18,207	63.1	−55.1	−0.1	22	0.005	N. 60° E...	4.3	Few S. Cu. SW.
6 48.0	18,511	60.2	−54.8	−0.1	23	0.005	S. 85° E...	13.9	
....	19,000	......	−53.2	......	23	0.006	S. 75° E...	10.1	
6 53.3	19,619	50.8	−51.4	−0.3	24	0.009	S. 63° E...	5.3	
....	20,000	......	−50.8	......	24	0.008	S. 4° E...	4.4	
6 57.0	20,389	45.1	−50.1	−0.2	24	0.009	S. 57° W..	3.4	Balloons disappeared.

JULY 27, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt / 100 m.	Humidity.		Wind.		Remarks.
					Rel.	Abs.	Direction.	Vel.	
P. M. 4 57.5	34	759.2	20.2	......	69	11.949	S. 86° W..	3.9	2/10 S. Cu. WSW.
....	500	......	13.6	......	83	9.687	S. 80° W..	2.9	
5 00.3	704	701.3	10.9	1.4	89	8.786	S. 77° W..	2.5	Inversion.
....	1,000	......	13.3	......	76	8.708	S. 47° E..	1.0	
5 02.3	1,087	669.9	13.8	−0.8	72	8.507	S. 83° E..	0.6	
5 04.2	1,388	646.3	14.0	−0.1	65	7.775	N. 41° W..	0.8	
....	1,500	......	13.2	......	64	7.288	N. 44° W..	0.8	
5 07.0	1,912	607.0	10.0	0.8	59	5.504	N. 56° W..	1.1	
....	2,000	......	9.6	......	55	5.003	N. 87° W..	1.2	
5 09.0	2,263	581.8	8.2	0.5	44	3.661	S. 1° E..	1.6	
....	2,500	......	6.2	......	39	2.852	S.......	1.8	
5 13.0	2,980	532.8	2.5	0.8	29	1.661	S. 3° W..	2.3	
....	3,000	......	2.5	......	29	1.661	S. 7° W..	2.3	
5 15.0	3,395	505.9	0.5	0.5	27	1.351	N. 85° W..	2.2	
....	3,500	......	−0.5	......	28	1.301	N. 86° W..	2.5	
....	4,000	......	−4.7	......	32	1.064	S. 89° W..	3.8	
5 20.5	4,454	442.6	−8.4	0.8	35	0.860	S. 85° W..	5.1	
....	4,500	......	−8.7	......	35	0.839	S. 85° W..	5.2	
....	5,000	......	−13.3	......	36	0.581	S. 83° W..	6.2	
5 25.0	5,292	396.5	−15.9	0.9	37	0.478	S. 82° W..	6.7	
5 26.1	5,510	385.2	−16.3	0.2	34	0.425	S. 78° W..	8.2	
....	6,000	......	−20.5	......	34	0.289	S. 75° W..	8.3	
5 30.0	6,422	340.8	−24.1	0.9	34	0.206	S. 73° W..	8.4	
5 32.0	6,853	321.5	−27.6	0.8	31	0.133	S. 85° W..	8.7	
....	7,000	......	−29.0	......	31	0.118	S. 81° W..	8.2	
....	8,000	......	−38.4	......	28	0.040	S. 50° W..	4.6	
5 38.9	8,361	259.9	−41.7	0.9	27	0.027	S. 39° W..	3.3	
....	9,000	......	−45.1	......	26	0.017	S. 57° W..	5.2	
5 46.0	9,905	206.6	−49.9	0.5	25	0.010	S. 83° W..	8.0	
....	10,000	......	−50.2	......	25	0.009	S. 83° W..	8.3	
....	11,000	......	−53.8	......	24	0.006	S. 82° W..	12.3	
....	12,000	......	−57.4	......	23	0.003	S. 82° W..	16.3	
5 56.6	12,029	149.3	−57.5	0.4	23	0.003	S. 82° W..	16.4	Inversion.
5 59.5	12,369	141.8	−56.6	−0.3	23	0.004	N. 87° W..	7.0	
....	13,000	......	−57.5	......	23	0.003	S. 83° W..	8.3	
....	14,000	......	−58.7	......	22	0.003	S. 67° W..	9.7	

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Continued.

JULY 27, 1913—Continued.

Time.	Altitude.	Pressure.	Temperature.	Δt / 100 m.	Humidity.		Wind.		Remarks.
					Rel.	Abs.	Direction.	Vel.	
P. M. h. m.	M.	Mm.	°C.		P. ct.	g./m³.		M.p.s.	
6 07.3	14,080	108.4	−58.7	0.1	22	0.003	S. 66° W..	9.9	2/10 S. Cu. WSW.
6 09.7	14,541	101.0	−61.1	0.5	21	0.002	N. 74° W..	7.4	
....	15,000	......	−61.5	......	21	0.002	N. 81° W..	7.3	
....	16,000	......	−62.2	......	21	0.001	S. 83° W..	7.0	
....	17,000	......	−63.0	......	21	0.001	S. 68° W..	6.8	
6 20.6	17,051	67.7	−63.1	0.1	21	0.001	S. 67° W..	6.8	Inversion.
....	18,000	......	−60.8	......	21	0.002	S. 2° W..	6.2	
6 28.5	18,797	51.4	−58.7	−0.3	21	0.003	S. 53° E..	5.7	
....	19,000	......	−58.7	......	21	0.003	S. 51° E..	5.3	
....	20,000	......	−57.8	......	21	0.003	S. 40° E..	3.6	
....	21,000	......	−57.0	......	21	0.003	S. 30° E..	1.9	
6 35.4	21,506	33.5	−56.5	−0.1	21	0.004	S. 25° E..	1.0	
....	22,000	......	−55.6	......	21	0.004	S. 36° E..	2.0	
....	23,000	......	−53.7	......	21	0.005	S. 59° E..	4.2	
6 41.5	23,870	23.0	−52.1	−0.1	21	0.006	S. 79° E..	6.1	Balloon burst.
....	23,000	......	−53.6	......	21	0.005	E......	11.3	
6 44.3	22,179	29.7	−55.1	1.0	21	0.004	N. 80° E..	16.2	Inversion.
....	22,000	......	−53.5	......	21	0.005	S. 88° E..	12.4	
6 45.4	21,821	31.3	−51.5	−0.4	21	0.007	S. 76° E..	8.2	
....	21,000	......	−54.3	......	21	0.005	S. 88° E..	10.9	
6 49.0	20,229	40.2	−57.2	−0.2	21	0.003	N. 80° E..	13.6	
....	20,000	......	−57.5	......	21	0.003	N. 77° E...	12.5	
6 51.1	19,098	48.0	−59.6	0.0	19	0.002	N. 67° E...	7.8	
....	19,000	......	−59.6	......	19	0.002	N. 70° E...	7.7	
....	18,000	......	−60.0	......	19	0.002	S. 84° E...	6.6	
....	17,000	......	−60.3	......	19	0.002	S. 57° E...	5.6	
6 57.9	16,916	67.9	−60.3	−0.4	19	0.002	S. 55° E...	5.5	
7 00.0	16,284	75.3	−63.1	−0.2	20	0.001	S. 34° E...	3.7	
....	16,000	......	−63.5	......	20	0.001	W........	3.6	
7 03.1	15,228	89.0	−64.7	0.1	19	0.001	N. 45° W..	3.4	Inversion.
....	15,000	......	−64.0	......	19	0.001	N. 58° W..	4.5	
7 09.0	14,178	105.3	−63.7	0.2	20	0.001	S. 76° W..	8.6	
....	14,000	......	−63.3	......	20	0.001	S. 77° W..	8.6	
7 11.9	13,498	117.5	−62.0	0.2	21	0.001	S. 79° W..	8.6	
....	13,000	......	−61.0	......	21	0.002	S. 60° W..	8.3	
7 15.1	12,734	132.4	−60.4	0.0	21	0.002	S. 50° W..	8.2	
7 17.0	12,323	141.4	−60.4	0.0	21	0.002	S. 62° W..	10.0	Balloons disappeared.
....	12,000	......	−60.4	......	21	0.002	....	......	
7 18.9	11,801	153.2	−60.2	0.4	21	0.002	....	......	
7 21.2	11,355	164.7	−58.5	0.6	21	0.003	....	......	
....	11,000	......	−56.2	......	21	0.004	....	......	
7 24.8	10,587	184.9	−53.6	0.8	21	0.005	....	......	
....	10,000	......	−49.1	......	22	0.010	....	......	
....	9,000	......	−41.6	......	23	0.023	....	......	
7 35.0	8,602	248.5	−38.6	0.6	24	0.033	....	......	
....	8,000	......	−35.0	......	24	0.049	....	......	
7 42.5	7,034	310.3	−29.4	0.1	25	0.092	....	......	
....	7,000	......	−29.4	......	25	0.092	....	......	
7 45.3	6,443	336.6	−28.6	0.7	30	0.117	....	......	
7 46.8	6,184	348.7	−26.9	0.5	31	0.143	....	......	
....	6,000	......	−26.0	......	33	0.167	....	......	
....	5,000	......	−20.8	......	42	0.347	....	......	
7 54.7	4,615	431.6	−18.8	2.0	46	0.460	....	......	
....	4,500	......	−16.6	......	45	0.548	....	......	
7 57.1	4,094	461.8	− 8.6	0.9	41	0.991	....	......	
....	4,000	......	− 7.8	......	41	1.057	....	......	
7 58.7	3,733	484.0	− 5.4	0.9	39	1.224	....	......	
....	3,500	......	− 3.4	......	39	1.441	....	......	
....	3,000	......	1.1	......	38	1.981	....	......	
8 04.3	2,980	532.3	1.4	0.4	38	2.021	....	......	
8 06.0	2,733	548.5	2.5	0.7	39	2.234	....	......	
....	2,500	......	4.1	......	40	2.549	....	......	
8 10.3	2,132	590.7	6.8	0.4	41	3.118	....	......	
....	2,000	......	6.3	......	49	3.607	....	......	
8 11.5	1,977	602.2	6.2	......	50	3.656	....	......	

JULY 28, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt / 100 m.	Humidity.		Wind.		Remarks.
					Rel.	Abs.	Direction.	Vel.	
P. M. 5 05.0	34	759.7	20.6	......	61	10.813	S.........	......	9/10 S. Cu. WNW.
5 06.8	371	730.3	15.8	1.4	68	9.073	S. 16° W..	3.7	
....	500	......	14.5	......	71	8.755	S. 33° W..	3.0	
5 08.7	787	694.9	11.7	1.0	77	7.991	S. 68° W..	1.5	
5 10.0	962	680.5	10.4	0.7	84	8.036	N. 67° W..	0.6	In base of S. Cu.
....	1,000	......	10.1	......	85	7.980	....	......	
5 10.9	1,117	667.8	9.7	0.5	86	7.872	....	......	Inversion.
5 11.4	1,218	659.9	15.0	−5.2	56	7.119	....	......	
5 12.3	1,377	647.4	16.2	−0.8	44	6.013	....	......	
....	1,500	......	16.2	......	39	5.330	....	......	
5 13.8	1,648	627.1	16.2	0.0	32	4.373	....	......	
5 15.2	1,923	607.1	15.4	0.3	29	3.777	....	......	
....	2,000	......	14.8	......	29	3.642	....	......	
....	2,500	......	10.0	......	32	2.985	....	......	
....	3,000	......	5.4	......	35	2.429	....	......	
5 20.3	3,048	530.1	5.0	0.9	35	2.366	....	......	
....	3,500	......	3.0	......	25	1.480	....	......	
5 22.9	3,535	499.1	3.0	0.4	24	1.421	....	......	
....	4,000	......	0.0	......	21	1.015	....	......	
5 27.4	4,498	442.6	− 2.8	0.6	18	0.698	....	......	
....	5,000	......	− 5.8	......	17	0.516	....	......	
5 31.6	5,406	394.3	− 8.1	0.6	16	0.403	....	......	
....	6,000	......	−12.7	......	16	0.272	....	......	
5 37.1	6,659	334.6	−18.1	0.8	16	0.171	....	......	
....	7,000	......	−21.4	......	16	0.125	....	......	
5 40.7	7,478	299.3	−26.3	1.0	16	0.078	....	......	
....	8,000	......	−30.7	......	16	0.051	....	......	
5 44.7	8,279	268.2	−33.0	0.8	16	0.040	....	......	

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Continued.

JULY 28, 1913—Continued.

Time.	Altitude.	Pressure.	Temperature.	Δt 100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
P. M. h. m.	M.	Mm.	°C.		P. ct.	g./m³.		M.p.s.	
	9,000		−37.8		15	0.023			
5 50.6	9,533	223.9	−41.5	0.7	14	0.014			
	10,000		−44.7		14	0.010			
5 55.2	10,399	197.3	−47.2	0.7	14	0.008			
	11,000		−50.6		14	0.005			
6 00.8	11,593	165.2	−53.6	0.5	13	0.003			
	12,000		−55.7		14	0.003			
6 04.9	12,233	149.5	−56.8	0.5	14	0.002			Inversion.
	13,000		−56.0		14	0.003			
6 09.3	13,096	131.0	−55.7	−0.1	14	0.003			Clock stopped at intervals. Time estimated.
6 11.3	13,293	127.1	−55.4	−0.2	13	0.003			
	14,000		−55.7		13	0.003			
6 15.5	14,084	112.6	−55.7	0.0	13	0.003			Clock stopped, but started again at highest altitude.
	19,485	48.1	−56.9	−0.1	13	0.002			
	19,000		−57.5		13	0.002			
	18,010	60.5	−58.8	−0.2	13	0.002			
	18,000		−58.8		13	0.002			
	17,000		−61.4		12	0.001			
	16,489	77.1	**−62.6**	0.0	12	0.001			Inversion.
	16,063	82.4	−62.4	0.2	12	0.001			
	16,000		−62.2		12	0.001			
	15,000		−60.1		13	0.001			
	14,253	109.6	−58.5		13	0.002			

JULY 29, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt 100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
A. M.									
11 10.0	34	760.5	18.6		63	9.933	N. 86° W.	2.5	9/10 S. Cu. NW.
11 11.3	418	726.8	15.2	0.9	73	9.393	N. 85° W.	2.5	
	500		14.5		76	9.372	N. 80° W.	2.3	
	1,000		10.6		92	8.913	N. 48° W.	1.3	
11 13.3	1,012	677.0	10.4	0.8	92	8.802	N. 47° W.	1.2	Balloon disappeared in S. Cu. Inversion.
11 14.8	1,330	651.6	9.4	0.3	97	8.713			
	1,500		11.2		76	7.645			
11 16.5	1,684	624.4	12.7	−0.9	55	6.073			
	2,000		12.2		44	4.711			
11 18.4	2,182	588.3	11.9	0.2	37	3.888			
	2,500		11.4		30	3.056			
11 20.2	2,625	557.8	11.3	0.1	27	2.733			
	3,000		9.3		22	1.964			
11 22.9	3,344	511.4	7.4	0.5	18	1.423			
	3,500		6.1		16	1.163			
	4,000		2.2		12	0.674			
11 25.7	4,041	469.4	1.8	0.8	11	0.601			
	4,500		− 2.9		10	0.384			
11 28.6	4,832	424.8	− 6.2	1.0	9	0.265			Inversion.
	5,000		− 6.2		9	0.265			
11 29.9	5,120	409.5	− 6.1	−0.3	9	0.267			
11 33.3	5,953	367.6	−13.4	0.9	7	0.112			
	6,000		−13.4		7	0.112			
11 35.0	6,272	352.7	−14.2	0.3	8	0.119			
11 36.1	6,629	336.2	−18.9	1.3	7	0.069			
11 37.4	6,908	324.5	−19.7	0.3	7	0.064			
	7,000		−20.4		7	0.060			
11 39.2	7,437	301.7	−23.7	0.8	5	0.032			
11 41.0	7,882	283.7	−27.8	0.9	5	0.021			
	8,000		−28.6		5	0.019			
11 43.2	8,570	257.7	−33.2	0.8	6	0.015			
	9,000		−36.4		6	0.011			
11 45.0	9,029	241.7	−36.7	0.8	6	0.010			
11 45.7	9,268	233.6	−38.2	0.6	7	0.010			
11 46.8	9,467	226.9	−39.1	0.5	7	0.009			
11 47.9	9,707	218.9	−42.5	1.4	7	0.006			Inversion.
11 48.1	9,928	212.2	−42.1	−0.2	7	0.007			
	10,000		−43.4		7	0.006			
11 49.4	10,248	202.8	−47.2	1.6	6	0.003			Inversion. One balloon burst and was detached; remaining balloon had sufficient lifting force to continue ascent.
11 53.0	10,633	191.3	−46.9	−0.8					
11 53.8	10,747	188.2	−47.3	0.4					
11 53.9	10,794	186.5	−48.3	2.1					
11 55.0	10,915	183.3	−48.7	0.3					Clock stopped.
	[a]11,000		[a]−49.3		[a] 5	0.002			
	[b]**23,066**	27.8	−44.3	−0.4					Balloon burst.
	23,000		−44.5						
	22,000		−49.5						
	21,305	36.3	−53.0	−0.2					
	21,000		−53.5						
	20,000		−55.2						
	19,000		−56.7						
	18,111	59.7	−58.4	0.0					
	18,000		−58.3						
	17,145	69.5	−58.5	−0.2					
	17,000		−58.7						
	16,141	81.4	**−60.4**	0.1					Inversion.
	16,000		−60.2						
	15,000		−59.2						
	14,344	107.9	−58.3	0.1	3	0.001			
	14,000		−58.3		3	0.001			
	13,000		−57.6		3	0.001			
	12,386	146.6	−57.3	0.0	3	0.001			
	12,000		−57.3		3	0.001			
	11,368	170.9	−57.3		4	0.001			
	11,000		−50.4		5	0.002			

[a] Estimated by extrapolation from the ascent.
[b] Balloon burst; clock started running, but times of this and succeeding levels unknown.

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Continued.

JULY 30, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt 100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
A. M. h. m.	M	Mm.	°C.		P. ct.	g./m³.		M.p.s.	
10 54.0	34	760.0	23.0		61	12.415	NE		Few Cu.
10 57.0	362	731.7	21.0	0.6	67	12.155	SE		
	500		19.9		70	11.913	S		
11 01.0	695	703.8	18.3	0.8	74	11.463	S. 50° W.	0.6	
11 03.0	884	688.3	16.9	0.7	80	11.402	S. 56° W.	1.8	Inversion.
	1,000		18.2		69	10.625	S. 1° W.	1.9	
11 06.0	1,184	664.5	19.9	−1.0	54	9.190	S. 86° W.	2.1	
11 07.3	1,338	652.7	20.4	−0.3	40	7.008	S. 42° E.	5.1	
	1,500		20.7		36	6.418	S. 38° E.	6.4	
11 12.3	1,766	621.1	21.3	−0.2	29	5.353	S. 32° E.	8.7	
11 13.9	1,927	609.5	20.7	0.4	26	4.636	S. 42° E.	12.8	
	2,000		20.3		34	5.922	S. 38° E.	12.4	
11 15.0	2,045	601.3	20.2	0.4	38	6.581	S. 35° E.	12.1	
11 16.9	2,185	591.5	19.6	0.4	45	7.525	S. 33° E.	15.8	Inversion.
11 18.9	2,413	576.7	20.4	−0.4	30	5.256	S. 32° E.	15.2	
11 20.0	2,499	570.3	20.1	0.3	24	4.132	S. 33° E.	14.8	
	2,500		20.0		24	4.108	S. 33° E.	14.8	
	3,000		18.5		15	2.351	S. 25° E.	16.0	
11 26.0	3,067	532.9	18.3	0.3	14	2.169	S. 24° E.	16.2	
11 29.0	3,339	516.7	16.1	0.8	11	1.494	S. 14° E.	17.8	
	3,500		14.8		11	1.381	S. 14° E.	17.2	
	4,000		11.0		10	0.993	S. 16° E.	15.4	
11 37.0	4,133	470.1	10.2	0.7	10	0.945	S. 16° E.	15.0	
11 39.0	4,362	457.3	8.2	0.9	10	0.832	S. 18° E.	17.1	Balloon disapp'd. Few Cu.
	4,500		7.2		10	0.780			
	5,000		3.8		11	0.687			
11 45.0	5,157	414.9	2.7	0.7	12	0.697			
11 49.3	5,749	385.4	− 1.1	0.6	9	0.399			
	6,000		− 3.5		9	0.330			
11 53.0	6,273	360.8	− 6.1	1.0	10	0.296			
11 55.5	6,672	342.7	− 9.2	0.8	10	0.230			
	7,000		− 9.8		10	0.219			
11 58.5	7,093	324.5	− 9.9	0.2	10	0.217			
P. M.									
12 01.0	7,475	309.1	−12.2	0.6	8	0.142			
	8,000		−15.9		8	0.103			
12 09.0	8,915	255.1	−22.1	0.7	7	0.051			
	9,000		−22.8		7	0.048			
	10,000		−30.2		6	0.020			
12 16.0	10,322	210.3	−32.6	0.7	6	0.016			Inversion.
12 17.0	10,521	204.6	−32.4	−0.1	6	0.016			
12 18.8	10,832	195.7	−35.6	1.0	6	0.012			
	11,000		−37.3		6	0.010			
12 22.9	11,724	172.1	−43.6	0.9	6	0.005			
	12,000		−44.2		6	0.004			
12 25.3	12,391	156.1	−44.9	0.2	6	0.004			
12 26.8	12,653	150.2	−48.4	1.3	6	0.003			
	13,000		−49.1		6	0.003			
	14,000		−51.3		6	0.002			
12 32.1	14,021	122.5	−51.3	0.2	6	0.002			Inversion.
	15,000		−49.2		6	0.003			
12 37.0	15,241	102.1	−48.6	−0.2	6	0.003			
12 37.8	15,435	99.3	−51.4	1.4	6	0.002			
	16,000		−50.3		6	0.002			
12 42.3	16,707	81.8	−49.0	0.2	6	0.003			
	17,000		−49.8		6	0.002			
	18,000		−53.0		6	0.002			
12 47.2	18,263	64.7	**−53.9**	0.3	6	0.001			Inversion.
12 50.1	18,877	58.9	−50.5	−0.6	5	0.002			
	19,000		−50.7		5	0.002			
	20,000		−52.3		5	0.001			
12 53.7	20,131	48.8	−52.5	0.2	5	0.001			Inversion.
	21,000		−51.4		5	0.002			
	22,000		−50.2		5	0.002			
	23,000		−49.0		5	0.002			
1 01.8	23,005	31.5	−49.0	−0.1	5	0.002			
1 03.9	23,932	27.3	−49.5	0.1	5	0.002			Inversion.
	24,000		−49.4		5	0.002			
	25,000		−47.7		5	0.003			
	26,000		−46.2		6	0.004			
	27,000		−44.5		6	0.004			
	28,000		−42.8		6	0.005			
1 11.0	28,062	14.7	−42.7	−0.2	6	0.005			
	29,000		−42.5		6	0.005			
	30,000		−42.4		6	0.005			
	31,000		−42.1		6	0.006			
	32,000		−41.9		6	0.006			
1 20.5	**32,643**	7.4	−41.8	0.0	6	0.006			
	32,000		−42.1		6	0.006			
	31,000		−42.9		6	0.005			
	30,000		−43.4		5	0.004			
	29,000		−44.0		5	0.004			
	28,000		−44.7		5	0.003			
	27,000		−45.4		5	0.003			
	26,000		−46.0		5	0.003			
1 24.9	25,118	22.7	−46.6	−0.1	3	0.003			
	25,000		−46.8		5	0.003			
	24,000		−49.4		5	0.002			
	23,000		−50.8		5	0.002			
(a)	22,249	35.1	−52.3	0.0	5	0.001			
	22,000		−52.4		5	0.001			
	21,000		−52.6		5	0.001			
	20,000		−53.0		5	0.001			
	19,051	57.2	−53.3	0.1	5	0.001			Inversion.
	19,000		−53.2		5	0.001			
	18,000		−52.4		5	0.001			
	17,000		−51.5		6	0.002			
	16,160	88.6	−50.8		6	0.002			
	16,000		−50.6		6	0.002			

[a] Clock stopped at intervals; times of this and subsequent levels unknown.

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Continued.

JULY 31, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt / 100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
A. M. h. m.	M.	Mm.	°C.		P.ct.	g./m³.		M.p.s.	
10 37.5	34	762.0	22.9		64	12.952			5/10 Ci. S.
10 39.3	388	731.3	18.0	1.4	74	11.261			
	500		18.0		74	11.261			
10 40.2	622	711.5	18.1	0.0	74	11.328			Inversion.
10 41.0	799	696.9	20.5	−1.4	63	11.102	S. 69° E.	1.5	
10 41.8	995	681.2	21.7	−0.6	46	8.690	S. 57° E.	5.6	
	1,000		21.6		46	8.640	S. 57° E.	5.6	
10 43.2	1,403	649.7	21.7	0.0	28	5.289	S. 58° E.	6.5	
	1,500		21.0		26	4.717	S. 52° E.	6.2	
10 45.6	1,898	613.4	19.2	0.5	16	2.613	S. 29° E.	5.1	
	2,000		18.7		15	2.379	S. 24° E.	5.8	
10 47.3	2,354	581.4	17.0	0.5	10	1.434	S. 8° E.	8.5	
	2,500		17.0		10	1.434	S. 20° E.	10.8	
10 48.3	2,542	568.6	17.0	0.0	10	1.434	S. 23° E.	11.5	
	3,000		12.8		13	1.444	S. 25° E.	9.4	
10 50.2	3,109	531.7	12.0	0.9	13	1.375	S. 25° E.	8.9	
	3,500		8.8		14	1.210	S. 22° E.	8.0	
10 52.0	3,588	501.7	8.1	0.8	14	1.158	S. 21° E.	7.7	
	4,000		5.8		12	0.855	S. 27° E.	11.2	
10 54.5	4,418	456.2	3.7	0.5	10	0.620	S. 33° E.	15.0	
	4,500		2.7		10	0.580	S. 33° E.	14.6	
	5,000		− 1.5		8	0.344	S. 34° E.	12.8	
10 57.3	5,041	419.5	− 1.8	0.9	8	0.336	S. 34° E.	12.7	
11 00.2	5,795	381.0	− 9.3	1.0	9	0.205	S. 36° E.	13.7	
	6,000		−11.3		10	0.193	S. 35° E.	14.6	
11 03.0	6,557	345.2	−16.7	1.0	12	0.145	S. 32° E.	16.9	
	7,000		−20.6		14	0.118	S. 26° E.	16.2	
11 06.0	7,430	307.0	−24.4	0.9	16	0.094	S. 20° E.	15.7	
	8,000		−28.6		16	0 062	S. 10° E.	14.4	
11 09.0	8,384	269.1	−31.3	0.7	16	0.048	S. 4° E.	13.6	Balloons disappeared in Cirrus clouds.
11 10.0	8,781	254.9	−32.8	0.4	16	0.041			
	9,000		−34.6		16	0.034			
	10,000		−42.2		15	0.014			
11 13.8	10,188	208.4	−43.6	0.8	15	0.012			5/10 Ci. S.
	11,000		−47.4		14	0.007			
11 18.2	11,725	166.0	−51.1	0.5	14	0.005			
	12,000		−52.3		14	0.004			
	13,000		−56.9		13	0.002			
11 21.2	13,165	132.9	−57.6	0.5	13	0.002			
11 22.6	13,533	126.0	−58.5	0.2	13	0.002			Inversion.
	14,000		−56.7		12	0.002			
11 23 9	14,154	114.2	−56.1	−0.4	12	0.002			
11 25 4	14,646	106.0	−54.5	−0.3	14	0.003			
	15,000		−55.4		14	0.003			
	16,000		−57.7		12	0.002			
11 29.6	16,166	83.7	−58.1	0.2	12	0.002			
11 30.1	16,600	78.1	−58.8	0.2	12	0.001			Inversion.
11 31.3	16,933	74.4	−58.4	−0.1	12	0.002			
	17,000		−58.6		12	0.001			
11 31.8	17,134	72.0	−58.9	0.2	12	0.001			Inversion.
	18,000		−58.0		12	0.002			
11 34.8	18,607	57.1	−57.6	−0.1	12	0.002			
	19,000		−56.4		13	0.002			
11 36.4	19,580	49.1	−54.6	−0.3	13	0.003			
	20,000		−53.7		13	0.003			
	21,000		−51.9		13	0.004			
11 40.3	21,352	37.4	−51.2	−0.2	13	0.004			
11 41.5	21,557	36.2	−51.3	0.1	12	0.004			Inversion.
	22,000		−49.8		13	0.005			
11 43.0	**22,194**	32.5	−48.6	−0.4	13	0.006			

AUGUST 1, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt / 100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
A. M.									
10 36.0	34	761.0	23.9		71	15.210			4/10 Ci. S.
10 36.8	179	748.4	20.0	2.7	74	12.667			Inversion.
10 38.0	365	732.4	22.4	−1.3	66	12.980			
	500		23.1		59	12.077			
10 40.0	707	704.1	24.4	−0.6	46	10.137	S. 8° W.	0.5	
10 40.9	859	691.8	24.7	−0.2	44	9.862	S. 44° E.	2.6	
	1,000		24.2		43	9.369	S. 39° E.	6.6	
10 41.9	1,015	679.6	24.2	0.3	42	9.151	S. 38° E.	7.3	
	1,500		22.0		42	8.072	S. 42° E.	8.1	
10 44.9	1,534	640.0	21.8	0.5	42	7.980	S. 42° E.	8.2	
	2,000		18.3		43	6.661	S. 43° E.	7.0	
	2,500		14.6		44	5.459	S. 44° E.	5.7	
10 51.1	2,555	567.8	14.0	0.8	44	5.263	S. 44° E.	5.5	
	3,000		10.9		48	4.739	S. 36° E.	6.1	
	3,500		7.4		54	4.268	S. 28° E.	6.7	
	4,000		3.6		59	3.367	S. 19° E.	7.4	
10 58.8	4,238	468.7	2.2	0.7	61	3.424	S. 15° E.	7.7	
11 00.7	4,432	451.7	1.9	0.2	44	2.420	S. 4° E.	8.3	
	4,500		1.5		43	2.302	S. 3° E.	8.5	
	5,000		− 1.6		39	1.662	S.	10.3	
11 05.5	5,381	400.9	− 4.0	0.6	36	1.266	S. 3° W.	11.6	
	6,000		− 9.5		37	0.831	S. 7° E.	10.1	
11 09.8	6,233	359.7	−11.6	0.8	37	0.694	S. 12° E.	9.5	Inversion.
11 10.4	6,296	356.7	−10.8	−1.3	38	0.765	S. 8° W.	15.6	
11 11.2	6,426	350.6	−13.7	2.2	37	0.576	S. 12° W.	14.8	
11 12.8	6,880	330.7	−16.8	0.7	37	0.443	S. 6° W.	16.0	
	7,000		−17.5		36	0.406	S. 1° E.	12.5	
11 14.9	7,218	315.8	−18.2	0.4	35	0.371	S. 13° E.	6.6	
	8,000		−23.5		31	0.199	S. 6° E.	8.3	
11 19.2	8,138	279.1	−24.3	0.7	30	0.178	S. 5° E.	8.6	
	9,000		−30.0		30	0.103	S. 2° E.	11.3	
	10,000		−36.6		31	0.054	S. 1° W.	14.3	
11 29.3	10,703	194.6	−41.4	0.7	31	0.031	S. 3° W.	16.5	Balloon disappeared in Ci.

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Continued.

AUGUST 1, 1913—Continued.

Time.	Altitude.	Pressure.	Temperature.	Δt / 100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
A. M. h. m.	M.	Mm.	°C.		P.ct.	g./m³.		M.p.s.	
	11,000		−43.2		31	0.026			
11 34.5	11,966	161.7	−49.5	0.6	31	0.013			
	12,000		−49.4		31	0.013			
11 36.0	12,366	152.5	−49.8	0.1	30	0.012			
11 37.2	12,827	142.1	−52.4	0.6	30	0.009			
	13,000		−52.3		30	0.009			
11 40.8	13,650	125.4	−52.4	0.0	31	0.009			Inversion.
11 42.7	13,977	119.4	−49.8	−0.8	31	0.012			
	14,000		−49.8		31	0.012			
11 45.2	14,778	106.0	−49.8	0.0	30	0.012			
	15,000		−50.5		30	0.011			
	16,000		−54.0		29	0.007			
11 53.9	16,717	78.7	−56.4	0.3	28	0.005			Inversion.
11 55.2	16,849	77.1	−55.5	−0.7	28	0.006			
	17,000		−56.0		28	0.005			
11 57.0	17,493	69.7	−57.3	0.3	28	0.004			
	18,000		−58.0		28	0.004			
12 00.0	18,395	60.6	−58.6	0.1	28	0.003			Inversion.
	19,000		−57.6		29	0.004			
P. M.									
12 03.3	19,993	47.3	−56.2	−0.2	30	0.006			
	20,000		−56.2		30	0.006			
12 06.0	20,195	45.7	−55.9	−0.1	30	0.006			
12 06.7	20,451	44.1	−54.2	−0.7	30	0.007			
12 07.2	20,675	42.6	−55.4	0.5	30	0.006			
	21,000		−55.0		30	0.006			
	22,000		−54.3		30	0.007			
	23,000		−53.5		30	0.008			
12 11.3	**23,466**	27.7	−53.1	0.2	30	0.008			
	23,000		−51.5		29	0.009			
12 12.6	22,792	30.8	−50.7	−0.1	28	0.010			
	22,000		−51.4		28	0.009			
12 15.6	21,226	38.7	−52.0	−0.2	28	0.008			
	21,000		−52.5		28	0.008			
	20,000		−55.0		28	0.006			
12 17.7	19,666	49.8	−55.7	0.4	28	0.006			Inversion.
12 18.7	19,273	52.9	−54.0	−0.1	28	0.007			
12 19.3	19,133	54.1	−55.4	−0.4	28	0.006			
	19,000		−55.7		28	0.006			
12 21.2	18,592	58.8	−57.3	0.4	28	0.004			Inversion.
	18,000		−54.6		29	0.007			
12 23.0	17,483	69.8	−52.4	−0.5	29	0.008			
12 25.3	17,054	74.6	−54.8	0.3	28	0.006			Inversion.
	17,000		−54.6		28	0.006			
12 25.7	16,773	77.7	−54.0	−0.2	28	0.007			
12 26.5	16,414	82.0	−54.8	0.2	29	0.006			Inversion.
	16,000		−53.8		29	0.007			
	15,000		−51.4		29	0.009			
12 32.4	14,227	114.8	−49.5	−0.2	29	0.012			
	14,000		−50.0		29	0.011			
12 34.5	13,254	132.9	−51.5	0.1	28	0.009			Inversion.
	13,000		−51.3		28	0.009			
12 37.6	12,441	150.0	−50.7	0.4					
	12,000		−48.9		30	0.013			
	11,000		−44.9		33	0.023			
12 42.0	10,857	190.0	−44.4	0.1	33	0.024			
	10,000		−37.9		35	0.052			
12 47.5	9,303	237.2	−32.7	0.8	37	0.096			
	9,000		−30.5		36	0.118			
12 51.7	8,188	276.8	−24.3	0.5	33	0.196			
	8,000		−23.5		33	0.212			
12 55.9	7,058	322.6	−19.2	0.9	34	0.328			
	7,000		−18.7		34	0.343			
	6.000		−10.2		36	0.762			
1 00.4	5,719	384.0	− 7.7	0.7	36	0.936			
1 02.8	5,115	414.9	− 3.6						
	5,000		− 3.0		37	1.411			

AUGUST 2, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt / 100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
A. M.									
10 59.0	34	761.0	25.1		69	15.817	E.		Inversion.
11 00.3	259	741.5	22.8	1.0	71	14.287			Cloudless.
11 01.5	437	726.5	26.7	−2.2	59	14.788			
	500		27.9		52	13.928			
11 02.7	584	714.5	29.0	−1.6	45	12.801			
11 04.0	753	701.0	30.0	−0.6	34	10.212	S. 83° W.	1.1	
11 05.0	907	689.0	29.0	0.6	29	8.250	S. 64° W.	3.3	
	1,000		28.5		28	7.750	S. 13° E.	2.3	
11 06.0	1,059	677.1	28.1	0.6	27	7.312	S. 62° E.	1.5	
11 07.0	1,197	666.6	27.4	0.5	24	6.253	S. 47° W.	3.7	
	1,500		25.4		25	5.828	S. 21° E.	3.3	
11 10.0	1,618	635.3	24.7	0.6	25	5.603	S. 48° E.	3.1	
	2.000		21.1		31	5.657	S. 33° E.	4.1	
11 14.5	2,289	587.7	18.4	0.9	35	5.454	S. 21° E.	4.9	Inversion.
11 14.9	2,328	584.7	19.1	−1.8	35	5.683	S. 12° E.	4.6	
	2,500		17.3		36	5.255	S. 9° E.	5.2	
	3,000		12.3		37	3.986	S. 1° E.	7.2	
11 19.6	3,015	539.0	12.2	1.0	37	3.961	S. 1° E.	7.3	Inversion.
11 20.0	3,053	536.2	12.6	−1.1	37	4.060	S. 7° E.	18.8	
11 22.0	3,307	520.1	10.6	0.8	33	3.197	S. 21° E.	7.2	
	3,500		9.9		30	2.781	S. 10° E.	7.4	
11 24.0	3,661	498.3	9.2	0.4	28	2.483	S. 1° E.	7.5	
	4,000		6.3		25	1.840	S. 6° E.	9.2	
11 29.0	4,437	453.2	2.9	0.8	22	1.294	S. 13° E.	11.4	
	4,500		2.3		22	1.243	S. 12° E.	11.2	
	5,000		− 0.6		20	0.922	S. 8° E.	10.4	
11 36.3	5,717	386.1	− 4.6	0.6	18	0.603	S. 2° E.	9.0	
	6,000		− 6.8		17	0.476	S.	9.0	

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Continued.

AUGUST 2, 1913—Continued.

Time.	Altitude.	Pressure.	Temperature.	Δt/100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
A. M. h. m.	M.	Mm.	°C.		P. ct.	g./m³.		M.p.s.	
11 42.5	6,789	336.8	−12.7	0.8	16	0.272	S. 7° W.	9.2	
	7,000		−14.4		16	0.235	S. 5° W.	9.6	
11 48.0	7,912	289.8	−21.7	0.8	15	0.114	S. 4° E.	11.6	
	8,000		−22.5		15	0.105	S. 2° E.	11.5	
	9,000		−28.5		14	0.055	S. 21° W.	11.0	
11 53.2	9,086	247.1	−29.0	0.6	14	0.053	S. 23° W.	10.9	
	10,000		−37.1		13	0.021	S. 26° W.	10.8	
12 00.0	10,591	199.3	−42.2	0.9	13	0.012	S. 28° W.	10.7	
P. M.									
	11,000		−45.6		13	0.008	S. 29° W.	11.0	
	12,000		−54.0		12	0.003	S. 30° W.	11.8	
12 05.5	12,031	161.1	−54.4	0.8	12	0.003	S. 30° W.	11.8	
	13,000		−55.2		13	0.003	S. 21° W.	21.7	
12 09.4	13,168	135.4	−55.3	0.8	13	0.003	S. 20° W.	23.3	Inversion.
12 11.0	13,449	130.0	−54.0	−0.5	13	0.003	S. 8° W.	19.3	
12 12.5	13,815	122.7	−55.0	0.3	13	0.003	S. 8° W.	24.3	Inversion.
	14,000		−54.1		13	0.003	S. 8° W.	23.0	
12 14.1	14,284	114.4	−52.8	−0.5	13	0.004	S. 8° W.	20.8	
12 16.1	14,541	110.1	−54.1	0.5	12	0.003	S. 31° W.	18.3	Inversion. One balloon burst and became detached; the remaining balloon had sufficient lifting force to continue ascent.
12 17.3	14,799	105.7	−50.3	−1.5	12	0.005	S. 50° W.	14.7	
	15,000		−50.9		12	0.004	S. 44° W.	18.4	
12 22.6	15,437	96.0	−52.1	0.3	12	0.004	S. 30° W.	27.2	
	16,000						S. 4° E.	19.7	
12 32.0	ᵃ16,890						S. 59° E.	7.4	Balloon disappeared. Few Cu.
12 56.4	21,302	35.5	−40.0	−0.5	10	0.012			
	21,000		−42.5		10	0.009			
	20,000		−50.6		10	0.004			
	19,000		−58.8		10	0.001			
12 57.9	18,990	53.9	−58.7	−0.3	10	0.001			
	18,000		−61.8		10	0.001			
	17,000		−63.9		10	0.001			
	16,000		−66.6		10	0.001			
1 00.0	15,828	89.0	−67.3	0.5	10	0.001			Inversion.
	15,000		−63.2		11	0.001			
	14,000		−58.5		13	0.002			
1 01.8	13,908	120.5	−58.0	0.0	13	0.002			
	13,000		−57.6		13	0.002			
	12,000		−57.3		13	0.002			
1 03.3	11,896	164.5	−57.1		13	0.002			

ᵃ Clock stopped. Altitude computed from ascensional rate.

AUGUST 3, 1913.

P. M.									
5 07.0	34	756.9	26.3		62	15.199			Few Cu. over mountains on mainland. Inversion.
5 07.7	233	739.8	24.1	1.1	62	13.433			
	500		30.0		40	12.014			
5 09.4	541	714.4	30.8	−2.2	37	11.604			
5 10.3	754	697.5	30.3	0.2	25	7.632	N. 65° W.	2.7	
5 11.3	879	687.7	30.6	−0.2	18	5.585	N. 65° W.	6.4	
	1,000		30.0		14	4.205	N. 62° W.	5.8	
5 13.0	1,079	672.3	29.5	0.5	11	3.216	N. 60° W.	5.4	
5 14.0	1,284	656.9	28.1	0.7	11	2.979	S. 81° W.	5.3	
	1,500		26.2		12	2.925	S. 75° W.	5.0	
	2,000		21.8		15	2.850	S. 60° W.	4.5	
5 19.9	2,398	577.7	18.4	0.9	17	2.649	S. 49° W.	4.0	
	2,500		17.7		17	2.541	S. 46° W.	4.2	
5 22.8	2,838	548.7	15.8	0.6	17	2.268	S. 36° W.	4.9	
	3,000		14.6		17	2.109	S. 25° W.	5.2	
	3,500		10.7		16	1.560	S. 9° E.	6.1	
5 28.0	3,804	488.8	8.4	0.8	15	1.264	S. 30° E.	6.6	
	4,000		7.3		15	1.178	S. 9° E.	5.2	
5 31.0	4,459	451.3	4.5	0.6	14	0.916	S. 39° W.	1.8	
	4,500		4.2		14	0.898	S. 42° W.	1.8	
5 34.0	4,996	422.0	− 0.2	0.9			S. 73° W.	2.2	
	5,000		− 0.5				S. 73° W.	2.3	
5 37.0	5,533	394.7	− 3.8	0.7			S. 70° W.	4.8	
5 39.0	5,792	381.8	− 6.6	1.1			S. 48° W.	4.6	
	6,000		− 8.2				S. 44° W.	4.2	
	7,000		−17.0				S. 22° W.	2.5	
5 45.8	7,183	318.9	−17.4	0.8			S. 18° W.	2.2	
	8,000		−24.5				S.	3.5	
5 52.0	8,308	273.7	−27.2	0.9			S. 7° E.	4.0	
	9,000		−31.1				S.	5.9	
5 58.0	9,573	229.7	−34.4	0.6			S. 6° W.	7.6	
	10,000		−36.8				S. 7° W.	7.7	
6 04.8	10,790	193.0	−41.5	0.6			S. 8° S.	7.9	
	11,000		−42.7				S. 9° W.	9.4	
	12,000		−49.2				S. 14° W.	16.4	
6 10.0	12,050	160.6	−49.7	0.7			S. 14° W.	16.8	
6 16.1	12,936	140.8	−49.9	0.0			S. 5° W.	22.3	
	13,000		−50.1				S. 7° W.	21.3	
6 18.1	13,315	132.8	−51.3	0.4			S. 16° W.	16.7	

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Continued.

AUGUST 3, 1913—Continued.

Time.	Altitude.	Pressure.	Temperature.	Δt/100 m.	Humidity. Rel.	Humidity. Abs.	Wind. Direction.	Wind. Vel.	Remarks.
P. M. h. m.	M.	Mm.	°C.		P. ct.	g./m³.		M.p.s.	
	14,000		−54.0				S. 22° W.	18.4	
6 24.0	14,729	107.0	−56.8	0.4			S. 29° W.	20.3	
	15,000		−59.2				S. 23° W.	18.2	
6 29.0	15,794	90.8	−65.7	0.8			S. 4° W.	12.2	Inversion.
6 30.1	15,975	88.2	−65.3	−0.2			S. 27° E.	9.4	
	16,000		−65.3				S. 26° E.	9.4	
6 33.0	16,611	79.4	−67.5	0.3			S. 2° W.	9.2	Inversion.
6 34.0	16,714	78.1	−66.9	−0.6			S. 34° E.	5.3	
6 35.7	16,895	76.0	−62.4	−2.5			S. 48° E.	9.1	
	17,000		−62.3				S. 45° E.	9.6	
6 38.4	17,428	69.4	−61.8	0.0			S. 31° E.	11.4	
	17,000		−61.5				S. 84° E.	17.9	
6 40.0	16,492	79.9	−61.2	−0.6			N. 32° E.	25.8	
	16,000		−64.3				S. 71° E.	12.5	
6 41.7	15,838	88.6	−65.4	0.0			S. 45° E.	7.8	
6 44.1	15,208	97.8	−65.4	0.6			S. 10° W.	20.3	Inversion.
	15,000		−64.0				S. 11° W.	19.6	
	14,000		−57.9				S. 15° W.	16.5	
6 50.0	13.118	135.3	−52.4	0.2			S. 18° W.	13.7	
	13,000		−52.2						
	12,000		−50.2						
6 54.3	11,782	166.0	−49.9	0.7					
	11,000		−44.5						
7 00.3	10,052	213.6	−37.8	0.8					
	10,000		−37.5						
	9,000		−29.4						
7 04.2	8,539	263.6	−25.9	0.7					
	8,000		−22.4						
7 10.0	7,080	321.0	−16.2	0.6					
	7,000		−15.7						
	6,000		− 9.4						
7 17.7	5,275	405.3	− 5.0	0.6					
	5,000		− 3.2						
	4,500		0.0						
	4,000		3.1						
7 24.1	3,792	487.7	4.3	0.8					
	3,500		6.6						
	3,000		10.6						
	2,500		14.5						
7 30.4	2,187	591.5	17.0	1.0					
	2,000		18.9						
	1,500		23.9						
7 34.1	1,208	662.5	26.7	0.9					
	1,000		28.5						
7 35.9	849	690.0	29.8	0.4					
7 36.7	718	700.3	30.3						

AUGUST 7, 1913.

P. M.									
4 52.0	34	756.4	21.4		78	14.482	E.	1.9	Few A. Cu., few S.
4 55.7	233	739.0	17.1	2.2	83	11.972	N. 51° W.	1.5	Inversion.
4 57.2	455	720.1	23.2	−2.7	70	14.411	S. 37° W.	2.0	
	500		23.7		66	13.979	S. 53° W.	2.2	
4 58.9	665	703.0	26.0	−1.3	49	11.813	N. 69° W.	3.5	
5 00.7	772	694.5	28.8	−2.6	30	8.441	N. 80° W.	6.8	
	1,000		29.9		21	6.274	N. 87° W.	7.1	
5 03.0	1,036	674.2	30.0	−0.5	20	6.007	N. 88° W.	7.2	
5 06.4	1,350	650.7	30.0	0.0	13	3.905	N. 82° W.	7.7	
5 07.8	1,440	644.1	28.8	1.3	10	2.814	N. 65° W.	4.5	
	1,500		29.5		9	2.631	N. 69° W.	6.4	Inversion.
5 09.4	1,534	637.4	29.8	−1.1	9	2.674	N. 72° W.	7.3	
5 12.7	1,741	622.6	27.0	1.4	6	1.529	N. 43° W.	5.1	
	2,000		26.9		6	1.521	N. 46° W.	6.5	
5 17.0	2,116	596.5	26.8	0.1	6	1.512	N. 48° W.	7.1	
	2,500		23.5		6	1.256	N. 7° E.	4.7	
5 23.0	2,551	567.5	22.8	0.9	6	1.207	N. 14° E.	4.2	
5 26.0	2,796	551.5	20.5	0.9	7	1.234	N. 8° W.	3.1	
	3,000		17.8		9	1.353	N. 7° E.	3.5	
5 35.6	3,459	510.1	11.8	1.3	12	1.253	N. 40° E.	4.5	
	3,500		11.1		13	1.300	N. 40° E.	4.6	5/10 A. Cu.; S.
	4,000		0.7		21	1.065	N. 34° E.	6.4	
5 46.0	4,087	472.3	− 0.7	2.0	22	1.007	N. 33° E.	6.7	At the base of A. Cu. 5:57 p. m. Balloons disappeared.
	4,500		− 7.2		48	1.299	N. 32° E.	7.8	
5 58.0	4,708	436.5	−10.2	1.6	61	1.292	N. 32° E.	8.4	
6 02.0	4,851	428.8	−12.7	1.7	62	1.056			
6 04.3	4,987	421.0	−12.9	0.1	80	1.338			Inversion.
	5,000		−12.7		80	1.362			
6 05.7	5,167	411.7	−11.7	−0.7	77	1.432			
6 14.0	5,575	390.3	−14.8	0.8	69	0.979			
6 20.0	5,881	374.8	−19.1	1.4	61	0.594			
6 24.0	5,967	370.4	−19.7	0.7	49	0.450			
	6,000		−19.9		48	0.432			
6 36.1	6,405	349.1	−24.4	0.8	34	0.221			
6 41.0	6,442	347.5	−25.2	0.5	31	0.169			

TABLE 4.—*Results of sounding balloon ascensions, Avalon, Cal.*—Concluded.

AUGUST 8, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt 100 m.	Humidity.		Wind.		Remarks.
					Rel.	Abs.	Direction.	Vel.	
P. M. h. m.	M.	Mm.	°C.		P. ct.	g./m³.		M.p.s.	
5 23.5	34	755.6	20.0	......	75	12.838	S. 32° W..	4.3	4/10 S. Cu. SSE.
5 25.1	367	726.6	17.2	0.8	80	11.608	S. 32° W..	4.3	
......	500	......	16.4	......	82	11.342	S. 62° W..	3.3	
5 26.7	786	691.5	14.4	0.7	88	10.785	N. 55° W..	0.9	Balloon in S. Cu. NW. Inversion.
......	1,000	......	19.8	......	67	11.336	N 6° E...	1.9	
5 27.4	1,021	672.6	20.4	−2.6	64	11.213	N. 12° E...	2.0	
5 28.4	1,122	664.7	21.8	−1.4	56	10.640	N. 16° E...	0.4	
5 29.1	1,244	655.4	24.5	−2.2	49	10.859	S. 69° E...	0.2	
5 29.5	1,413	642.9	24.9	−0.2	45	10.200	S. 77° W..	1.0	
......	1,500	......	24.4	......	43	9.476	N. 82° W..	1.5	
5 30.2	1,539	633.6	24.2	0.6	42	9.151	N. 73° W..	1.8	Inversion.
5 30.7	1,711	621.3	24.3	−0.1	41	8.984	N. 45° W..	5.2	
......	2,000	......	23.1	......	39	7.983	N. 21° W..	6.0	
5 32.3	2,080	595.4	22.6	0.5	39	7.758	N. 15° W..	6.2	
......	2,500	......	19.3	......	40	6.572	N. 25° W..	3.6	
5 34.3	2,619	559.2	18.4	0.8	40	6.233	N. 28° W..	2.8	
......	3,000	......	14.5	......	41	5.055	N. 20° W..	4.1	
5 36.9	3,316	514.7	11.4	1.0	41	4.176	N. 13° W..	5.2	
......	3,500	......	9.8	......	43	3.961	N. 10° W..	4.6	
......	4,000	......	5.8	......	46	3.278	N. 2° W..	3.2	
5 40.5	4,198	462.6	4.2	0.8	48	3.079	N. 1° E...	2.7	
......	4,500	......	2.2	......	50	2.806	N. 17° W..	3.0	
5 43.4	4,981	419.9	− 0.9	0.7	53	2.387	N. 45° W..	3.4	
......	5,000	......	− 1.0	......	53	2.368	N. 45° W..	3.4	
5 46.8	5,982	369.6	− 6.5	0.6	57	1.634	S. 50° W..	3.0	
5 47.1	5,997	368.4	− 6.9	2.7	59	1.637	S. 53° W..	5.8	
......	6,000	......	− 6.8	......	58	1.623	S. 53° W..	3.0	
5 48.0	6,299	354.5	− 8.7	0.6	58	1.390	S. 75° W..	5.5	Inversion.
5 49.2	6,615	......	− 8.4	−0.1	54	1.326	S. 45° W..	3.6	Pressure pen not recording. Altitude computed from ascensional rate.
5 50.0	6,840	......	− 8.1	−0.1	52	1.308	S. 22° W..	14.6	
......	7,000	......	− 8.9	......	50	1.180	S. 11° W..	12.0	
5 50.8	7,050	......	− 9.1	0.5	49	1.137	S. 7° W..	10.7	
5 53.2	7,750	......	−13.0	0.6	46	0.763	S. 14° W..	11.5	
......	8,000	......	−14.5	......	45	0.655	S. 16° W..	12.8	
5 54.8	8,215	......	−15.9	0.6	45	0.582	S. 18° W..	14.0	6/10 S. Cu. SSE. Balloons disappeared in St. Cu. Observations of ascension were made through this film of St. Cu. which at times obscured balloons after 5 26.5 p. m.
5 56.2	8,650	......	−19.5	0.8	45	0.422	....	......	
5 56.8	8,850	......	−20.7	0.6	45	0.375	....	......	
......	9,000	......	−21.3	......	44	0.346	....	......	
5 57.7	9,080	......	−21.7	0.4	44	0.334	....	......	
5 59.8	9,700	......	−24.3	0.4	43	0.256	....	......	
......	10,000	......	−26.1	......	43	0.215	....	......	
6 02.2	10,415	......	−28.7	0.6	42	0.162	....	......	
6 03.1	10,730	......	−29.8	0.3	42	0.145	....	......	
......	11,000	......	−31.5	......	42	0.124	....	......	
6 05.8	11,575	......	−35.0	0.6	42	0.086	....	......	
......	12,000	......	−35.8	......	41	0.077	....	......	
6 07.5	12,080	......	−36.0	0.2	41	0.076	....	......	
6 09.4	12,700	......	−37.2	0.2	40	0.065	....	......	
......	13,000	......	−38.7	......	40	0.055	....	......	
6 11.2	13,250	......	−39.8	0.5	40	0.049	....	......	
......	14,000	......	−43.4	......	40	0.033	....	......	
6 13.8	**14,100**	......	**−43.9**	0.5	40	0.031	....	......	

AUGUST 10, 1913.

Time.	Altitude.	Pressure.	Temperature.	Δt 100 m.	Rel.	Abs.	Direction.	Vel.	Remarks.
A. M.									
4 43.0	34	765.9	23.4	......	58	12.077	N. 46° E...	2.8	Cloudless.
4 45.7	435	722.6	21.3	0.5	57	10.522	N. 24° E...	1.1	Inversion.
......	500	......	21.9	......	52	9.937	N. 5° E...	1.7	
4 48.2	832	690.3	24.7	−0.9	27	6.052	N. 89° W..	4.0	
......	1,000	......	24.5	......	21	4.654	S. 88° W..	3.5	
4 49.2	1,036	674.3	24.5	0.1	20	4.432	S. 87° W..	3.4	
......	1,500	......	23.3	......	15	3.106	N. 47° W..	2.3	
4 52.4	1,549	635.7	23.2	0.3	14	2.882	N. 42° W..	2.1	
4 54.9	**1,976**	604.8	**19.3**	0.6	15	2.464	N. 47° W..	2.1	One balloon became detached; the other balloon with the meteorograph slowly descended.
......	2,000	......	19.0	......	15	2.421	N. 47° W..	2.1	
......	1,500	......	21.0	......	13	2.358	N. 43° W..	2.2	
5 00.9	1,385	647.8	21.5	0.7	13	2.428	N. 42° W..	2.2	
5 03.0	1,253	657.7	22.4	0.8	9	1.770	N. 23° W..	2.1	
......	1,000	......	24.5	......	8	1.773	N. 44° W..	1.8	
5 09.0	785	694.2	26.2	−0.3	7	1.706	N. 61° W..	1.5	
5 11.0	702	700.8	24.1	0.2	7	1.517	N. 68° W..	3.9	Inversion. Balloon disappeared behind the mountains.
5 13.1	600	709.0	24.3	−0.5	7	1.534	....	......	
......	500	......	23.7	......	16	3.389	....	......	
5 16.6	360	728.9	23.0	−1.8	27	5.495	....	......	
5 18.3	263	737.1	21.3	......	44	8.122	....	......	Inversion.

(b) THE CAPTIVE BALLOON AND MOUNTAIN OBSERVATIONS ON AND NEAR MOUNT WHITNEY.

By W. R. GREGG.

Meteorological observations, including some captive balloon ascensions, were made at Mount Whitney, Cal., from August 1 to 13, inclusive, and at Lone Pine, Cal., from August 1 to 4, inclusive. Mount Whitney is the highest peak of the Sierra Nevadas, its altitude being 4,420 meters. It lies in latitude 36° 35′ N. and longitude 118° 17′ W. On the north, south, and west it is surrounded by mountains, many of which are nearly as high as itself; its eastern slope is quite precipitous and at its foot lies Owens Valley, which is about 25 kilometers in width and extends in a north-northwest and south-southeast direction. East of this valley and running parallel to the Sierras is the Inyo Range, altitude about 3,000 meters. Lone Pine is situated about midway between these two ranges, near the northern end of Owens Lake. Its altitude is 1,137 meters and it lies in latitude 36° 35′ N. and longitude 118° 3′ W., about 25 kilometers due east from Mount Whitney. Topographically the location of Lone Pine is similar to that of Independence, Cal., which is about 25 kilometers north-northwest of it and therefore practically the same distance from Mount Whitney. Independence is in latitude 36° 48′ N., longitude 118° 12′ W., and has an altitude of 1,191 meters, or 54 meters higher than that of Lone Pine.

SURFACE OBSERVATIONS AT MOUNT WHITNEY.

The instrumental equipment consisted of a Short and Mason aneroid barometer, sling psychrometer, small kite anemometer of the Robinson type, Marvin meteorograph, and Richard meteorograph. The Richard instrument recorded pressure and temperature only and the object in taking it was to obtain a surface record of these elements and also to provide a substitute in case the Marvin instrument were lost or injured. The latter recorded relative humidity in addition to pressure and temperature. In order to secure good ventilation during balloon ascensions a section of the horizontal screening tube containing the humidity and temperature elements had been cut out, thus exposing these elements directly to the air.

As soon as they were unpacked, both of these instruments were started recording and a continuous record of pressure, temperature, and relative humidity was obtained. The sheets were changed at 8 a. m. and 5 p. m., and eye readings of the aneroid barometer and psychrometer were taken at these times—at 11 a. m. and 2 p. m., and during balloon ascensions. In addition, readings of the psychrometer were taken by Messrs. A. K. Ångström and E. H. Kennard, representing the Smithsonian Institution, during the nights when they were observing. These readings have also been used to check the meteorograph records.

The exposure of the instruments was fairly good. They were kept in an improvised shelter constructed from the boxes in which they were "packed" to the summit. The ventilation was good, but during those afternoons in which the sun shone, the air in the shelter was considerably heated. However, there were only four sunny afternoons, and furthermore the eye readings at 2 p. m. and 5 p. m. leave but little interpolation necessary.

All of the instruments were calibrated before and after the expedition. Especial care was taken in the calibration of the aneroid barometer, tests being made to determine the correction for "lag" or "creeping" and for changes in temperature. The effect of the latter was found to be negligible.

Owing to the large scale value of the pressure elements in the meteorographs and to the effect of changes of temperature on those elements, it is impossible to obtain with much accuracy the hourly values. However, in Table 5 are given the pressures observed at certain hours. The readings at 11 a. m. are uniformly higher than those at 8 a. m., 2 p. m., or 5 p. m. It is probable that the diurnal maximum occurs at about this time.

The range of pressure for the entire period is large, about 8 mm. The range for the same period at Independence is much less, about 5 mm. At both places the lowest readings were recorded on August 8 and 9, while a cyclonic disturbance was central over northern California. This low was attended by considerable cloudiness, with thunderstorms, and, at Mount Whitney, snowstorms. The greater pressure range at Mount Whitney than at Independence is accounted for by the cool weather during the passage of the low and the consequent crowding together of the isobars in the lower levels.

Tables 6, 7, and 8 contain the hourly values of temperature, relative humidity, and absolute humidity, respectively. Means have been computed for the 10 complete days, August 3 to 12, inclusive. Final conclusions may not be drawn from so short a record, but a few comparisons are of interest. The mean temperature was 0.7° C.; that in the free air at the same altitude and for the same time of year, as determined from five years' observations at Mount Weather, Va., is −2.0°. The mean temperature at Pikes Peak [1] for these 10 days in 1893 and 1894 was 2.8°. Pikes Peak has an altitude of 4,301 meters, or about 100 meters below that of Mount Whitney, and to correct for this difference in altitude about 0°.6 should be subtracted from the value at Pikes Peak. The temperature at Mount Whitney was undoubtedly below normal, owing to the severe stormy weather which prevailed. However, the values at both places, compared with those at the same altitude above Mount Weather, indicate that in summer temperatures on mountains are higher than those in the free air, although difference in latitude, in this case about 2½°, should be considered. The times of maximum and minimum temperatures at Mount Whitney were 3 p. m. and 5 a. m., respectively; at Pikes Peak they were 1 p. m. and 5 a. m., respectively.

Figure 10 shows mean hourly temperatures at Mount Whitney and Independence and for the same period during 1893 and 1894 at Pikes Peak. The range at the latter appears to be somewhat smaller than at Mount Whitney, and this may be due to the fact that conditions at Pikes Peak are more nearly like those of the free air, owing to its isolation and the consequent freer circulation. The curve for Independence shows the large diurnal range characteristic of valley stations. Beneath the mean temperatures for Mount Whitney in Table 6 are given the means for the same period at Independence and the differences in temperature change per 100 meters altitude between the two places. The temperature change with altitude during the night hours is somewhat misleading, owing to a marked inversion of temperature between the surface of the valley and about 200 meters above it, as will be pointed out in discussing the Lone Pine observations. The hourly differences between Independence and Mount Whitney during the daytime are large, averaging about 0.85. The mean for the 24 hours is 0.73.

Fig. 8.—Pressure distribution in the western United States, July 29–August 13, 1913.

[1] Annual Reports of Chief U. S. Weather Bureau, 1893, 1894, 1895–96, Washington.

TABLE 5.—*Pressures at Mount Whitney, Cal., Aug. 1–13, 1913.*

Date.	Hours. A. M.												P. M.												Means.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
1913.					Mm.			Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.		Mm.			Mm.	Mm.			Mm.	
Aug. 1																									
2																	447.0								
3									446.8	447.0	447.6	447.0	447.0	446.8	446.5		446.0				446.5				
4								446.8				448.1		446.0			445.8			446.3				446.0	
5								445.5			446.3			446.5			445.5								
6								444.2			445.0			444.8			444.5			444.8					
7								444.8			445.3			445.3			443.5								
8								442.7			442.5			441.4			440.7								
9								438.7			439.2			438.9			438.9								
10								440.4			441.2			440.4			440.2								
11								441.4			442.0			441.7			440.4								
12								440.9			441.7			440.9			440.4								
13					438.7																				

TABLE 6.—*Hourly temperatures at Mount Whitney, Cal., Aug. 1–13, 1913.*

Date.	Hours. A. M.												P. M.												Means.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
1913.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	
Aug. 1																							−2.9*		
2																			1.1	−0.1	−0.6	−1.1*	−1.2	−1.4*	
3	−1.4*	−1.9*	−2.1	−2.8	−2.9	−2.5	−1.8	0.0*	1.0	2.2*	1.7*	3.9*	2.3*	3.1*	6.1*	5.6	4.8	3.2	1.4*	0.2*	−0.2*	0.0	−0.1*	−0.4*	0.8
4	−0.6*	−1.1*	−1.1	−1.3*	−1.7*	−1.8	−1.0	−0.7*	−0.7	0.7	2.1	3.9*	4.4	4.8*	4.9	5.0	4.7*	4.5	1.9*	1.4*	1.3*	1.1*	0.6*	0.6*	1.3
5	0.6*	0.2*	0.2*	−0.1*	−0.3	−0.1	0.9	1.8*	1.7	3.0	4.2*	5.0	5.8	6.6*	7.0	5.5	4.3*	4.0	1.9*	1.8*	1.2*	1.1*	1.1*	0.6*	2.4
6	0.3*	0.6*	0.3*	0.6*	(0.6)	(1.2)	(1.6)	2.0*	2.3	3.8	5.0*	5.6	6.2	6.2*	6.4	6.6	7.8*	7.5	4.5	2.5*	2.2	2.1	2.0	2.0	3.3
7	1.9	1.8	1.7	1.6	1.6	1.6	1.7	1.9*	3.0	3.3	4.4*	5.2	5.9	6.7*	7.0	6.8	3.9*	4.4	3.8	1.9	1.4	1.5	1.5	1.4	3.2
8	1.0	0.7	0.5	0.5	0.5	0.4	0.5	1.3*	1.3	−0.2	−0.7*	0.2	0.2	−0.8*	−0.3	0.3	1.0*	1.0	0.2	−0.6	−1.1	−1.3*	−1.4	−1.4	0.1
9	−1.5	−1.5*	−1.5	−1.5	−1.5	−1.7	−1.8	−2.0*	−2.4	−0.4	−1.3*	−1.0	−0.5	−0.2*	−2.0	−1.1	−1.1*	−1.3	−2.3	−2.2	−2.2	−2.4	−2.6	−2.7	−1.6
10	−3.1	−3.4	−3.6	−3.7	−3.7	−3.2	−1.9	−0.9*	−1.0	−0.8	−0.2*	0.0	−0.7	−0.5*	−0.5	−3.0	−0.7*	−0.9	−1.2	−1.7	−2.2	−2.3	−2.3	−2.4	−1.8
11	−2.4	−2.4	−2.5	−2.7	−2.8	−2.8	−2.8	−2.6*	−2.6	−1.0	−0.1*	0.3	1.4	2.2*	2.7	2.5	2.4*	2.0	−0.6	−2.2*	−2.3*	−2.4*	−2.7*	−2.8	−1.0
12	−3.0*	−2.8	−2.6*	−2.5*	−2.5	−2.5	−1.4	−0.2*	−0.2	1.3	2.8*	3.4	4.4	5.2*	5.6	4.0	4.0*	4.0	−0.3	−1.2	−1.4	−1.6	−1.3	−1.4	0.4
13	−2.0	−2.4	−2.5	−2.6	−3.3*																				
Means	−0.8	−1.0	−1.1	−1.2	−*1.3*	−1.1	−0.6	0.1	0.2	1.2	1.8	2.6	2.9	3.3	3.7	3.2	3.1	2.8	0.9	0.0	−0.3	−0.4	−0.5	−0.6	0.7
Independence means	18.6	17.8	17.2	*16.3*	16.5	16.7	20.4	22.9	25.2	26.9	29.2	30.6	31.2	31.4	31.4	31.3	29.9	27.7	26.1	25.3	23.7	22.0	20.4	19.8	24.1
Δt per 100m	0.60	0.58	0.57	0.54	0.55	0.55	0.65	0.71	0.78	0.80	0.85	0.87	0.88	0.87	0.86	0.87	0.83	0.77	0.78	0.79	0.75	0.70	0.65	0.63	0.73

* Eye readings.

TABLE 7.—*Hourly relative humidities at Mount Whitney, Cal., Aug. 1–13, 1913.*

Date.	Hours. A. M.												P. M.												Means.
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
1913.																									
Aug. 1																							97*		
2																						75*		93*	
3	92*	92*	(80)	42	(50)	(60)	(70)	79*	(80)	80*	79*	74*	81*	76*	55*	60	68	71	80*	78*	85*	78	70*	72*	73
4	69*	71*	55	36*	45*	50	64	64*	68	(74)	77	77*	72	51*	60	62	62*	67	75*	66*	51*	45*	52*	51*	61
5	52*	52*	47*	50*	51	52	55	56*	48	40	32*	34	34	36*	40	45	49*	52	54*	51*	55*	43*	38*	42*	46
6	43*	40*	29*	34*	(42)	(50)	(58)	67*	64	50	57*	(58)	(59)	60*	58	57	57*	55	58	70	70	70	70	66	56
7	68	68	69	69	69	69	69	69*	68	65	63*	63	64	64*	66	68	70*	75	100	100	95	94	93	93	75
8	93	93	92	92	92	91	85	78*	80	92	93*	96	100	100*	100	100	82*	82	84	85	86	86*	84	85	90
9	86	87*	87	87	88	90	94	95*	95	(92)	89*	85	90	100*	100	98	97*	99	100	100	100	99	99	98	94
10	96	93	90	85	80	85	87	86*	85	86	95*	93	92	91*	88	100	93*	94	100	100	94	99	100	100	92
11	100	100	100	96	94	94	63	50*	41	41	41*	41	41	41*	45	73	77*	72	67	63*	41*	40*	33*	31	62
12	31*	26	20*	18*	18	30	40	50*	48	46	43*	43	43	43*	47	56	62*	50	72	76	54	54	15	15	42
13	15	19	19	19	23*																				
Means	73	72	67	*61*	63	67	68	69	68	67	67	66	68	66	66	72	72	72	79	79	73	71	65	66	69

TABLE 8.—*Absolute humidities in grams per cubic meter at Mount Whitney, Cal., Aug. 1–13, 1913.*

Date.	Hours. A. M. 1	2	3	4	5	6	7	8	9	10	11	12	P. M. 1	2	3	4	5	6	7	8	9	10	11	12	Means.
1913.																									
Aug. 1																							3.7*		
2																						3.3*		4.0*	
3	4.0*	3.8*	(3.3)	1.6	(1.9)	(2.4)	(2.9)	3.8*	(4.1)	4.5*	4.3*	4.7*	4.6*	4.5*	4.0*	4.2	4.5	4.3	4.3*	3.8*	4.0*	3.8	3.4*	3.4*	3.8
4	3.2*	3.1*	2.4	1.6*	1.9*	2.1	2.9	2.9*	3.1	(3.8)	4.3	4.8*	4.7	3.4*	4.0	4.2	4.1*	4.4	4.1*	3.5*	2.7*	2.3*	2.6*	2.6*	3.3
5	2.6*	2.5*	2.3*	2.4*	2.4	2.5	2.8	3.1*	2.6	2.4	2.1*	2.3	2.4	2.7*	3.1	3.1	3.2*	3.3	3.0*	2.8*	2.9*	2.2*	2.0*	2.1*	2.6
6	2.1*	2.0*	1.4*	1.7*	(2.1)	(2.6)	(3.1)	3.7*	3.6	3.1	3.9*	(4.1)	(4.3)	4.4*	4.3	4.3	4.6*	4.4	3.8	4.0*	3.9	3.9	3.9	3.7	3.5
7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.8*	4.0	3.9	4.1*	4.3	4.6	4.8*	5.1	5.2	4.4*	4.9	6.2	5.5	5.1	5.0	5.0	4.9	4.4
8	4.8	4.7	4.6	4.6	4.6	4.5	4.3	4.1*	4.2	4.4	4.3*	4.7	4.9	4.5*	4.7	4.9	4.2*	4.2	4.1	3.9	3.8	3.8*	3.6	3.7	4.3
9	3.7	3.7	3.7	3.7	3.8	3.8	3.9	3.9*	3.8	(4.3)	3.9*	3.8	4.2	4.8*	4.1	4.3	4.3*	4.3	4.0	4.1	4.1	4.0	3.9	3.8	4.0
10	3.6	3.4	3.3	3.1	2.9	3.2	3.6	3.9*	3.8	3.9	4.5*	4.5	4.2	4.2*	4.1	3.8	4.3*	4.2	4.4	4.2	3.8	4.0	4.0	4.0	3.9
11	4.0	4.0	4.0	3.7	3.6	3.6	2.4	2.0*	1.6	1.9	2.0*	2.0	2.2	2.3*	2.6	4.2	4.4*	4.0	3.1	2.6*	1.7*	1.6*	1.3*	1.2	2.8
12	1.2*	1.0	0.8*	0.7*	0.7	1.2	1.7	2.4*	2.3	2.4	2.5*	2.6	2.8	2.9*	3.3	3.5	3.9*	3.2	3.4	3.3	2.3	2.3	0.7	0.6	2.2
13	0.6	0.8	0.8	0.7	0.9																				
Means	3.3	3.2	3.0	2.7	2.8	3.0	3.1	3.4	3.3	3.5	3.6	3.8	3.9	3.8	3.9	4.2	4.2	4.1	4.0	3.8	3.4	3.3	3.0	3.0	3.5

*Indicates eye-readings. ( ) inclose estimated values. All others from meterograph records.

TABLE 9.—*Wind velocities, in meters per second, at Mount Whitney, Cal., during August, 1913.*

Date.	Hours. A. M. 1	2	3	4	5	6	7	8	9	10	11	12	P. M. 1	2	3	4	5	6	7	8	9	10	11	12
1913.																								
Aug. 1																								
2																			←	—	2.6	—	—	—
3	←	—	—	—	2.6	—	—	—	—	→	1.3	1.8	1.8	1.3	1.3	1.8	—	*	2.1	→	3.6	←	3.8	—
4	←	—	—	—	3.8	—	—	—	*	3.8	—	→	2.2	—	*	1.5	—	*	1.3	→	2.5	—	—	→
5	←	—	—	—	1.8	—	—	—	*	1.5	—	*	2.8	—	*	2.1	—	*	—	—	3.4	—	—	—
6	—	—	—	—	3.4	—	—	—	*	0.9	—	*	1.9	—	*	1.2	—	*	—	—	3.6	—	—	—
7	—	—	—	—	3.6	—	—	—	*	3.7	—	*	3.5	—	*	3.6	—	*	—	—	3.0	—	—	—
8	—	—	—	—	3.0	—	—	—	*	2.4	—	*	3.1	—	*	1.5	—	*	—	—	2.0	—	—	—
9	—	—	—	—	2.0	—	—	—	*	2.8	—	*	2.4	—	*	3.7	—	*	—	—	1.4	—	—	—
10	—	—	—	—	1.4	—	—	—	*	1.4	—	*	2.1	—	*	2.8	—	*	—	—	3.5	—	—	—
11	—	—	—	—	3.5	—	—	—	*	4.1	—	*	3.7	—	*	3.7	—	*	—	—	3.7	—	—	—
12	—	—	—	—	3.7	—	—	—	*	4.9	—	*	5.7	—	*	4.6	—	*	—	—	5.6	—	—	—
13	—	—	—	—	5.6	→																		

Mean velocity for entire period, 3 m. p. s.
NOTE.—Anemometer read at the times indicated by *; figures are mean velocities between readings.

TABLE 10.—*State of weather at Mount Whitney, Cal., during August, 1913.*

Date.	Hours. A. M. 1	2	3	4	5	6	7	8	9	10	11	12	P. M. 1	2	3	4	5	6	7	8	9	10	11	12	Remarks.
1913.																									
Aug. 1																	←	—	—	Cloudy.		→	Clear	←	*, ☈ until 10 p. m.
2	—	—	—	—	—	—	—	—	—	—	—	Cloudy.	—	—	—	—	→	Pt. Cldy.		Clear.		—	—	—	*, ☈ in p. m.
3	→	Pt. cldy.		Clear.		Pt. cldy.		←	—	—	—	Cloudy.	—	→	←	Pt. cldy.		→	←	Clear.		—	—	—	≡ 2a, Cu. from SE.
4	—	—	—	—	—	—	—	—	—	—	—	Clear.	—	—	—	→	Pt. cldy.		←	Clear.		—	—	—	Cu. from S. ⚡ in NE. in evening.
5	—	—	—	—	—	—	—	—	—	—	—	Clear.	—	—	—	—	—	—	—	—	—	—	—	—	Cu. & Cu. N. from S.; ⚡ in NE. in evening.
6	—	—	—	—	Clear.		—	—	—	—	—	→	←	—	—	Pt. cldy.		→	←	Clear.		—	—	—	Cu. & Cu. N. from S.; ☈ near by in p. m.
7	—	—	—	—	Clear.		—	—	→	←	—	Pt. cldy.	—	—	→	←	—	—	—	Cloudy.		—	—	—	☈ nearby; * 5:30 p.—12 p.
8	—	—	—	—	—	—	—	—	—	—	—	Cloudy.	—	—	—	—	—	—	—	→	Pt. cldy.		Clear.		*^{2}—4:30 p.
9	Clear	Pt. cldy.		←	—	—	—	—	—	—	—	Cloudy.	—	—	—	—	—	—	—	→	←	Pt. cldy.		—	Snow squalls. *^{2} 6 p.; ≡^{2}.
10	Pt. cldy.	←		Clear.		→	←	Pt. cldy.		→	←	Cloudy.	—	—	—	—	—	—	—	—	—	—	—	→	*^{2} 9:30 a. —9 p.
11	←	Pt. cldy.		→	←	—	—	—	—	—	—	Clear.	—	—	—	—	—	—	—	—	—	—	—	—	Cu. from east and southeast.
12	—	—	—	—	—	—	—	—	—	—	—	Clear.	—	—	—	—	—	—	—	—	—	—	—	→	Cu. from south.
13	←	Pt. cldy.		—	—	→																			Ci. and S. cu. from south.

The relative humidity, Table 7, was probably higher than normal for this season of the year, owing to the unusually stormy weather and the presence of snow on the ground. The mean was 69 per cent, the mean maximum 79 per cent at 7 to 8 p. m., and the mean minimum 61 per cent at 4. a. m. During the severe storm of August 8, 9, and 10, 100 per cent was frequently recorded. The absolute minimum was 15 per cent at midnight of the 12th.

For the reasons given above, the absolute humidity, Table 8, was also probably higher than normal. The mean was 3.5 grams per cubic meter, the mean maximum 4.2 at 4 to 5 p. m., and the mean minimum 2.7 at 4 a. m. The absolute maximum was 6.2 at 7 p. m. of the 7th and the absolute minimum 0.6 at midnight of the 12th.

Table 9 gives roughly the average wind velocities. Dial readings of the anemometer were made at the times

indicated by stars. The figures between these stars represent average velocities for the intervals between readings. The mean for the entire period was 3.0 m. p. s. That at Pikes Peak for the same time of year was 6.0 m. p. s. This difference may be due partly to the fact that Pikes Peak stands out in the open, whereas Mount Whitney is surrounded by peaks nearly as high as itself, and also to the greater proximity of Pikes Peak to the cyclonic storm paths of the United States. The prevailing wind direction was southeast, but directions ranging between south and northeast were frequently observed, and a southwesterly wind prevailed during the blizzard of August 9.

In Table 10 may be found the state of the weather for the period, together with notes on storms, kinds of clouds, and miscellaneous phenomena.

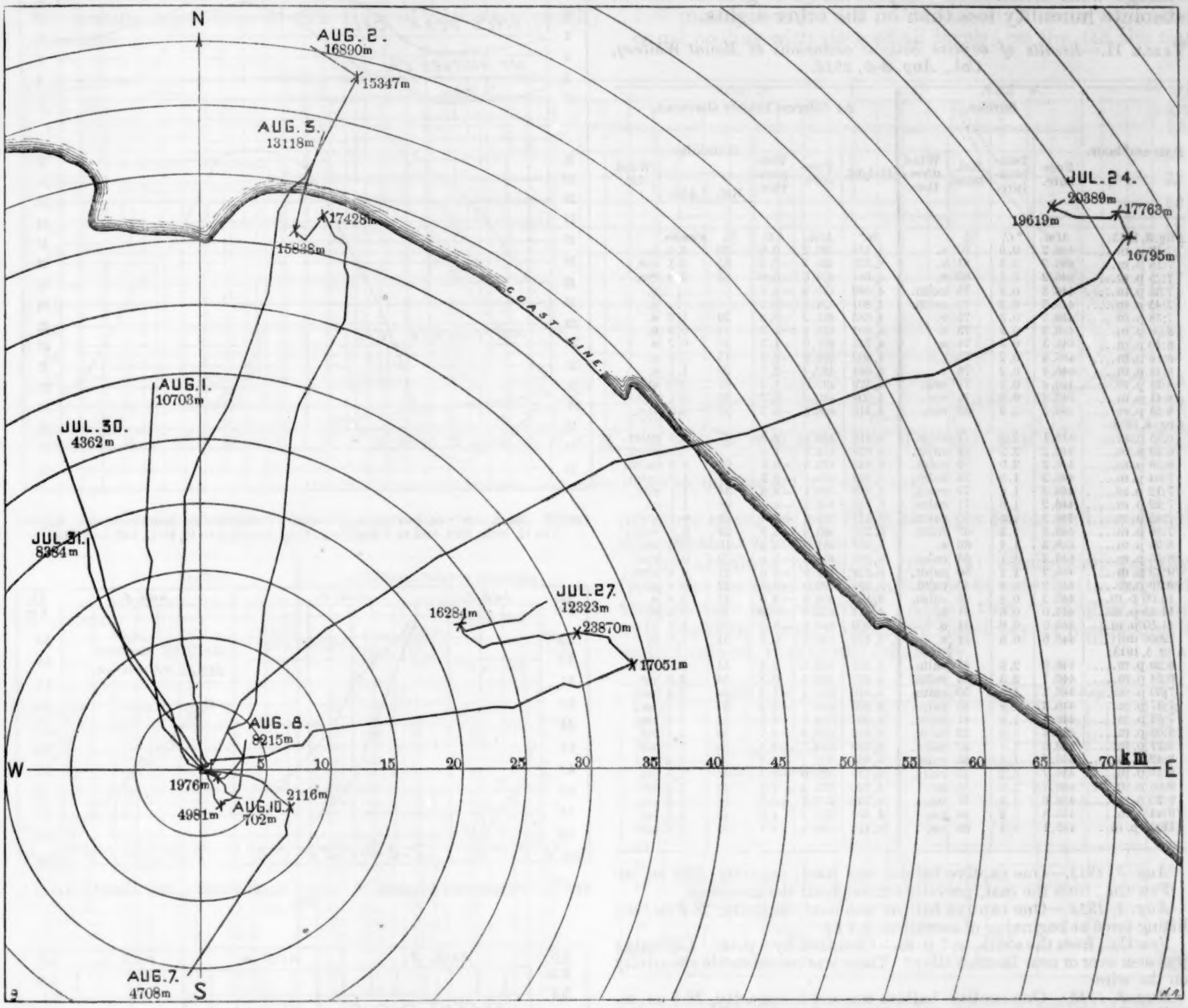

FIG. 9.—Horizontal projections of the paths of the sounding balloons liberated at Avalon, Cal., July 23–August 10, 1913.

FREE-AIR OBSERVATIONS AT MOUNT WHITNEY, CAL.

The place from which balloon ascensions were made was about 60 meters to the northwest of the summit of Mount Whitney and about 10 meters below it. This was the only spot on the mountain that was fairly level and free from jagged surface rocks. While the balloon was being filled with gas it rested on a large piece of canvas to protect it from rocks and snow. The gas, compressed in steel cylinders, was furnished by the Signal Corps of the United States Army. A hand reel was used for reeling the wire in and out. Readings of the psychrometer, aneroid barometer, and anemometer were made with the aid of a pocket electric flash lamp.

Ascensions were made on only three nights, August 3, 4, and 5, and were begun immediately after sundown. On all other nights the weather was either too windy or too stormy. The balloon was allowed to take as great an altitude as possible and was then kept out until the wind aloft had increased to such an extent that it was necessary to reel in.

Table 11 contains the tabulated data for the three records obtained, and in figures 11 and 12 are plotted the temperature and absolute humidity gradients, re-

spectively; the slight changes with time at the higher levels in each ascension are not plotted; only the ascent and descent proper. On August 3 and 4 these elements diminished with time by nearly the same amounts at all upper levels as at the surface. There was but little wind during these nights. An August 5, however, there was a fairly high northeast wind aloft and the temperature and humidity changed very little with time. The change with altitude in temperature was greater and in absolute humidity less than on the other nights.

TABLE 11.—*Results of captive balloon ascensions at Mount Whitney, Cal., Aug. 3-5, 1913.*

Date and hour.	Surface.				At different heights above sea.					
	Pressure.	Temperature.	Rel. hum.	Wind direction.	Height.	Pressure.	Temperature.	Humidity. Rel.	Humidity. Abs.	Wind dir.
Aug. 3, 1913:	*Mm.*	*°C.*	%		*M.*	*Mm.*	*°C.*	%	*g/cu.m.*	
7:13 p. m.	446.2	0.6	80	s.	4,410	446.2	0.6	80	4.0	s.
7:18 p. m.	446.2	0.3	81	s.	4,533	439.3	−0.2	65	3.1	ese.
7:25 p. m.	446.2	0.1	80	s.	4,631	434.0	−0.9	65	2.9	ese.
7:35 p. m.	446.3	0.3	78	calm.	4,689	430.9	−1.5	......	......	e.
7:45 p. m.	446.3	0.2	78	calm.	4,801	424.9	−2.3	......	......	e.
7:58 p. m.	446.3	0.3	75	e.	4,683	431.2	−0.8	29	1.3	e.
8:06 p. m.	446.3	0.3	73	e.	4,801	424.9	−1.5	18	0.8	e.
8:10 p. m.	446.3	0.3	74	e.	4,744	427.9	−1.3	16	0.7	e.
8:15 p. m.	446.4	0.2	75	e.	4,802	424.9	−2.3	13	0.5	e.
8:18 p. m.	446.4	0.2	76	e.	4,664	432.4	−2.0	26	1.1	e.
8:31 p. m.	446.4	0.1	78	ene.	4,579	437.0	−1.5	67	2.9	ene.
8:41 p. m.	446.4	0.0	79	ene.	4,509	440.9	−0.7	68	3.1	ene.
8:51 p. m.	446.5	−0.2	85	ene.	4,410	446.5	−0.2	85	4.0	ene.
Aug. 4, 1913:										
6:45 p. m.	446.1	2.3	77	calm.	4,410	446.1	2.3	77	4.4	calm.
6:49 p. m.	446.2	2.2	78	calm.	4,627	434.3	1.4	......	......	calm.
6:56 p. m.	446.2	2.0	76	calm.	4,852	422.3	−0.9	64	2.9	calm.
7:04 p. m.	446.2	1.8	74	calm.	5,104	409.1	−2.2	37	1.5	calm.
7:12 p. m.	446.2	1.6	72	calm.	5,359	396.1	−4.8	34	1.1	ssw.
7:22 p. m.	446.2	1.6	71	calm.	5,230	402.6	−4.4	33	1.1	s.
7:45 p. m.	446.3	1.6	70	calm.	5,316	398.3	−5.6	24	0.7	wsw.
7:56 p. m.	446.3	1.3	67	calm.	5,216	403.3	−4.9	23	0.8	wsw.
8:25 p. m.	446.3	1.1	60	e.	5,258	401.2	−4.4	19	0.6	sw.
8:55 p. m.	446.2	1.1	55	calm.	5,201	404.0	−3.6	12	0.4	ssw.
9:13 p. m.	446.2	1.1	50	calm.	5,229	402.6	−3.6	12	0.4	ssw.
9:39 p. m.	446.2	0.9	46	calm.	5,299	399.0	−5.6	12	0.4	s.
10:00 p. m.	446.2	0.8	45	calm.	5,198	404.0	−4.3	12	0.4	s.
11:45 p. m.	446.0	0.6	51	e.	4,634	433.6	−1.9	10	0.4	e.
11:50 p. m.	446.0	0.6	51	e.	4,509	440.5	−0.7	23	1.1	e.
12:00 mdt.	446.0	0.6	51	e.	4,410	446.0	0.6	51	2.6	e.
Aug. 5, 1913:										
6:38 p. m.	446.0	2.8	51	calm.	4,410	446.0	2.8	51	3.0	calm.
6:54 p. m.	446.1	2.5	52	calm.	4,625	434.3	0.8	54	2.8	sw.
7:30 p. m.	446.2	1.8	50	calm.	4,810	424.4	−1.4	54	2.3	ne.
7:37 p. m.	446.3	1.8	45	calm.	4,995	414.7	−2.8	54	2.1	ne.
7:52 p. m.	446.4	1.9	47	calm.	4,997	414.7	−3.5	54	2.0	ne.
8:05 p. m.	446.4	1.8	53	calm.	4,898	419.9	−2.7	54	2,1	ne.
8:17 p. m.	446.5	1.7	57	calm.	4,999	414.7	−3.4	54	2.0	ne.
8:42 p. m.	446.6	1.3	55	calm.	4,861	422.1	−1.8	54	2.3	ne.
8:56 p. m.	446.7	1.2	55	calm.	4,736	428.9	−0.3	53	2.5	ne.
9:05 p. m.	446.7	1.3	55	ne.	4,820	424.4	−1.1	53	2.4	ne.
9:20 p. m.	446.6	1.3	51	ne.	4,734	428.9	−0.3	51	2.4	ne.
9:44 p. m.	446.5	1.2	46	ne.	4,604	435.8	1.0	48	2.5	ne.
11:00 p. m.	446.1	1.1	38	ne.	4,410	446.1	1.1	38	2.0	ne.

Aug. 3, 1913.—One captive balloon was used; capacity, 28.6 cu. m. Few Cu., from the east, prevailed throughout the ascension.

Aug. 4, 1913.—One captive balloon was used; capacity, 28.6 cu. m.; lifting force at beginning of ascension, 5.4 kg.

Few Cu., from the south, at 7 p. m. Cloudless by 9 p. m. Lightning was seen over or near Death Valley. There was considerable electricity on the wire.

Aug. 5, 1913.—One captive balloon was used; capacity, 28.6 cu. m. Few Cu., direction unknown, in early evening. Cloudless after 8.50 p. m. Lightning was seen on the eastern horizon, near Death Valley.

TABLE 12.—*Temperature differences at 100-meter intervals above Mount Whitney, Cal., Aug. 3, 4, 5, 1913.*

Observations.	Altitudes (meters).								
	100	200	300	400	500	600	700	800	900
Aug. 3, 1913:									
Ascent	0.6	0.8	0.9	0.6	......	......	......	......	......
Descent	0.5	1.0	0.4	0.2	......	......	......	......	......
Aug. 4, 1913:									
Ascent	0.4	0.4	0.9	1.0	0.7	0.5	0.6	1.0	1.0
Descent	1.3	1.0	0.5	0.4	0.5	0.4	0.4	0.4	0.4
Aug. 5, 1913:									
Ascent	0.9	1.0	1.1	1.2	0.8	0.8	......	......	......
Descent	0.1	0.1	0.9	1.2	1.1	1.2	......	......	......
Means	0.63	0.72	0.77	0.77	0.78	0.72	0.50	0.70	0.70

Table 12 contains the temperature differences at 100-meter intervals above the surface, as observed in all three ascensions. The mean gradient is 0.70 and is fairly constant at all altitudes up to 900 meters.

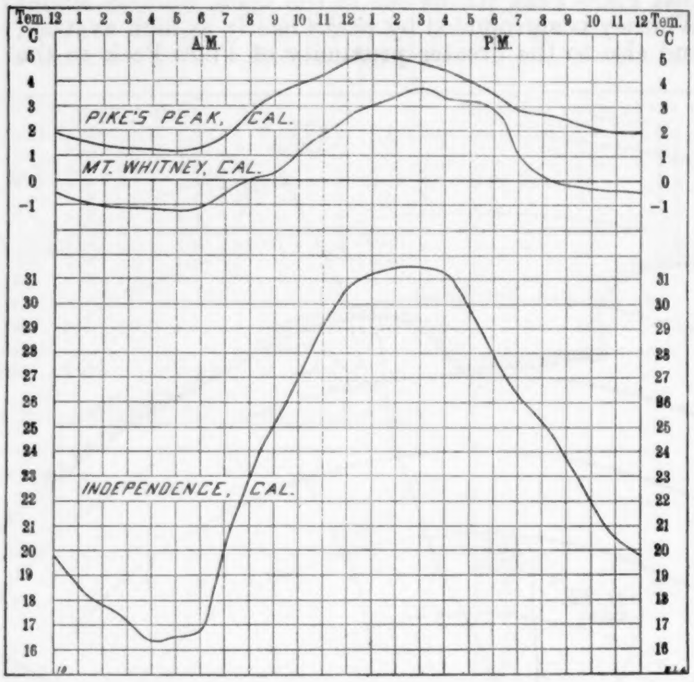

FIG. 10.—Mean hourly temperatures at Mount Whitney and Independence, Cal., August 3 to 12, incl., 1913, and at Pikes Peak, Col., August 3 to 12, incl., 1893 and 1894.

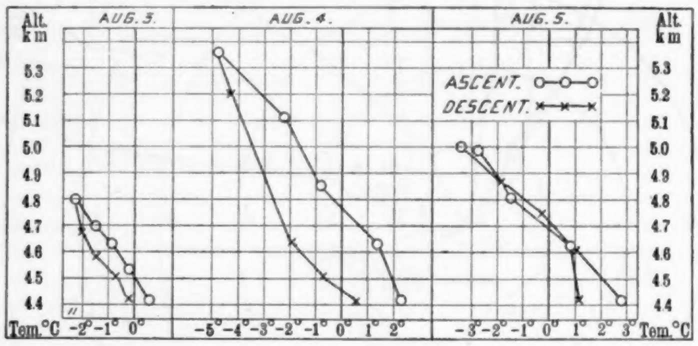

FIG. 11.—Temperature gradients (°C.), above Mount Whitney, Cal., August 3, 4, and 5, 1913.

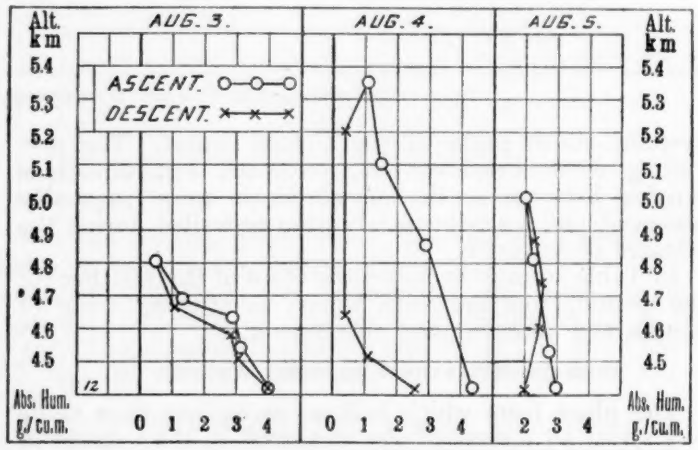

FIG. 12.—Absolute humidity gradients, grams per cubic meter, above Mount Whitney, Cal., August 3, 4, and 5, 1913.

FREE-AIR OBSERVATIONS AT LONE PINE, CAL.

The balloon ascensions were carried out by Mr. P. R. Hathaway from a place about 1 kilometer north of Lone Pine. The instrumental and other equipment was similar to that used at Mount Whitney. Owing to leakage of a large number of gas tubes, only four ascensions were possible. These were made on August 1, 2, 3, and 4 and were begun shortly after sundown. Surface conditions for making ascensions at this time of day were usually excellent.

The records obtained in the balloon ascensions are given in tabular form in Table 13. Figures 13 and 14 show the temperature and absolute humidity gradients, respectively. There was always a marked inversion of temperature between the surface and 200 meters above it, amounting on the average to 6° C. (See Table 14.) From 200 to 300 meters there was practically no change, but above 300 meters the temperature decreased with altitude at a fairly uniform rate, the mean difference per 100 meters being 0.73. On August 2 there was about equal cooling with time at all levels; on the 4th the temperature changed but little at upper levels and increased somewhat at the surface.

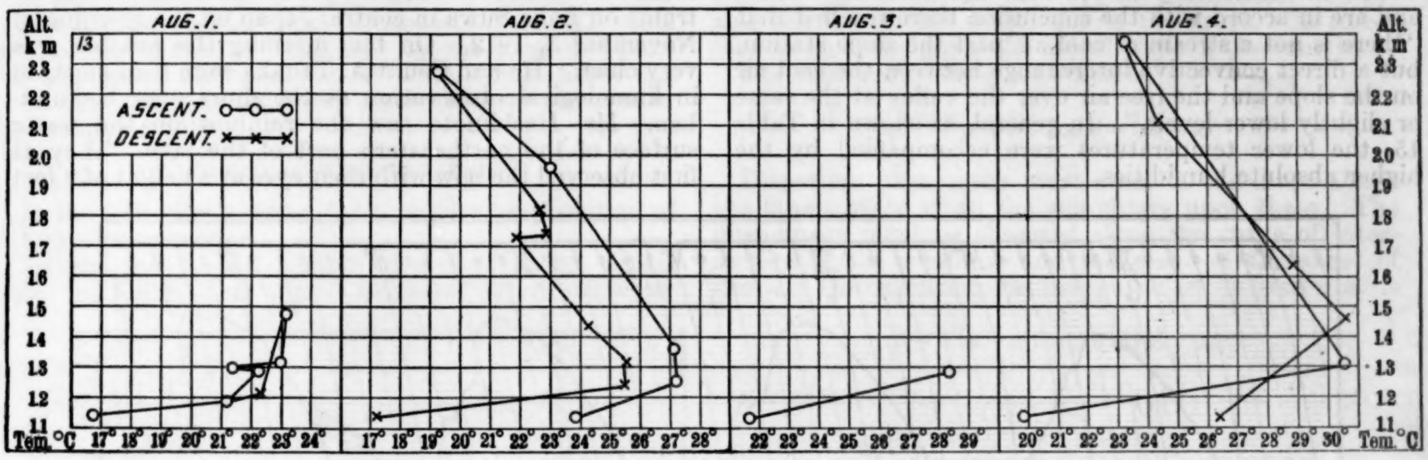

FIG. 13.—Temperature gradients (°C.), above Lone Pine, Cal., August 1, 2, 3, and 4, 1913.

TABLE 13.—*Results of captive balloon observations at Lone Pine, Cal., Aug. 1–4, 1913.*

Date and hour.	Surface.				At different heights above sea.					
	Pressure.	Temperature.	Rel. hum.	Wind direction.	Height.	Pressure.	Temperature.	Humidity. Rel.	Humidity. Abs.	Wind dir.
Aug. 1, 1913:	*Mm.*	*°C.*	%		*M.*	*Mm.*	*°C.*	%	*g/cu.m.*	
9:18 p. m...	660.3	16.7	79	calm.	1,137	660.3	16.7	79	11.1	calm.
9:30 p. m...	660.4	16.7	79	calm.	1,190	656.3	21.1	50	9.1	w.
9:37 p. m...	660.5	16.8	78	calm.	1,296	648.5	22.2	37	7.2	w.
9:44 p. m...	660.6	17.2	77	calm.	1,297	648.5	21.4	37	6.9	w.
10:10 p. m..	660.8	18.3	72	w.	1,311	647.7	23.0	28	5.7	w.
10:15 p. m..	660.8	16.7	80	calm.	1,470	636.0	23.1	24	4.9	w.
10:43 p. m..	661.0	16.7	78	s.	1,204	655.8	22.3	46	9.0	s.
10:48 p. m..	661.1	16.7	78	s.	1,137	661.1	16.7	78	11.0	s.
Aug. 2, 1913:										
7:38 p. m...	658.3	23.9	46	nnw.	1,137	658.3	23.9	46	9.9	nnw.
7:41 p. m...	658.5	24.2	45	nnw.	1,253	649.9	27.2	30	7.7	n.
7:47 p. m...	658.8	22.6	48	nnw.	1,355	642.8	27.1	17	4.4	n.
8:01 p. m...	659.3	19.4	64	s.	1,958	600.4	23.0	17	3.5	calm.
8:48 p. m...	660.0	19.7	57	calm.	2,273	579.8	19.2	23	3.8	se.
9:30 p. m...	660.9	18.6	66	calm.	1,811	612.1	22.7	20	4.0	se.
10:48 p. m..	662.6	17.5	69	s.	1,734	618.9	22.9	20	4.0	sw.
10:56 p. m..	662.8	18.0	64	s.	1,728	619.7	21.9	21	4.0	sw.
11:05 p. m..	662.9	16.4	77	s.	1,432	641.0	24.3	23	5.0	se.
11:13 p. m..	662.9	16.7	75	s.	1,316	649.4	25.6	21	5.0	e.
11:19 p. m..	662.9	17.0	70	w.	1,234	655.5	25.5	21	4.9	e.
11:25 p. m..	662.9	17.2	70	w.	1,137	662.9	17.2	70	10.2	w.
Aug. 3, 1913:										
7:17 p. m...	661.8	21.7	54	calm.	1,137	661.8	21.7	54	10.2	calm.
7:21 p. m...	661.9	21.7	54	calm.	1,296	650.0	28.4	26	7.2	sse.
9:25 p. m...	664.5	22.9	37	ssw.	1,137	664.5	22.9	37	7.5	ssw.
Aug. 4, 1913:										
7:19 p. m...	656.9	19.9	58	calm.	1,137	656.9	19.9	58	9.9	calm.
7:22 p. m...	657.0	19.8	57	calm.	1,309	644.4	30.6	......	......	se.
7:34 p. m...	657.4	21.0	43	calm.	2,367	572.2	23.2	......	......	se.
7:56 p. m...	658.2	22.2	39	s.	2,106	589.9	24.4	......	......	sse.
8:02 p. m...	658.3	22.7	38	s.	1,629	622.7	28.9	......	......	sse.
8:05 p. m...	658.3	23.0	38	s.	1,459	634.9	30.6	......	......	sse.
8:55 p. m...	658.2	26.4	27	s.	1,137	658.2	26.4	27	6.7	s.

Aug. 1, 1913.—One captive balloon was used; capacity, 28.6 cu.m. Cu. Nb., from the west, decreased from 5/10 to a few. Light rain fell for about two minutes at 9.35 p. m.

Aug. 2, 1913.—One captive balloon was used; capacity, 31.1 cu.m. St. Cu., from the south, decreased from 6/10 to a few.

Aug. 3, 1913.—One captive balloon was used; capacity, 31.1 cu.m. 1/10 Cu., direction unknown, disappeared before the end of the ascension.

Aug. 4, 1913.—One captive balloon was used; capacity, 31.1 cu.m. The sky was cloudless.

The absolute humidity (fig. 14) diminished rapidly from the surface to the altitude at which the highest temperature was recorded. Above this, on August 2, the only night in which a record of humidity at higher levels was obtained, it diminished slowly.

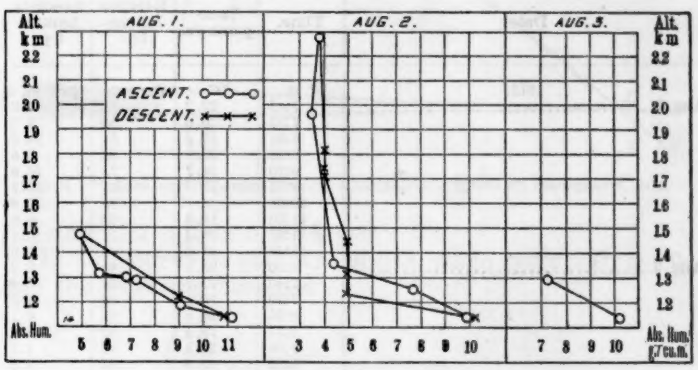

FIG. 14.—Absolute humidity gradients, grams per cubic meter, above Lone Pine, Cal., August 1, 2, and 3, 1913.

TABLE 14.—*Temperature differences at 100-meter intervals above Lone Pine, Cal., Aug. 1–4, 1913.*

Observations.	Altitude (meters). 100	200	300	400	500	600	700	800	900	1,000	1,100	1 200
Aug. 1, 1913:												
Ascent...........	−4.8	−1.5	−0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....
Descent..........	−5.7	−0.3	−0.3	.....	.....	.....	.....	.....	.....	.....	.....	.....
Aug. 2, 1913:												
Ascent...........	−2.7	−0.5	.05	0.7	0.7	0.7	0.7	0.6	1.1	1.2	1.2	.....
Descent..........	−8.3	0.1	1.1	0.8	0.8	−0.2	0.4	0.7	0.8	0.7	0.8	.....
Aug. 3, 1913:												
Ascent...........	−4.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Aug. 4, 1913:												
Ascent...........	−6.2	−4.3	0.7	0.7	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.7
Descent..........	−1.3	−1.3	−1.3	0.5	1.0	0.9	1.0	0.9	0.9	0.8	0.5	0.5
Means.........	−4.74	−1.30	0.10	0.68	0.80	0.52	0.68	0.72	0.88	0.85	0.80	0.60

During the day there was a moderate breeze from the north blowing down the valley. This became very light toward evening, and at about the same time the temperature began to fluctuate, sudden changes of 2° to 5° C. occurring frequently between 6 p. m. and the time of minimum temperature. These fluctuations are well shown in the thermograph records at Independence, Cal. (fig. 15), and in Table 15, which contains observed temperatures and humidities at Lone Pine, Cal. These observations have been referred to by Dr. Wm. R. Blair in his discussion of mountain and valley temperatures (Bull., Mt. Weather obs'y, Washington, 1914, **6**: 122) and are in accord with the conclusion there reached that "there is not a stream of cool air past the slope station, but a direct convective interchange between the cool air on the slope and the free air over the valley at the same or slightly lower levels." In general, as shown in Table 15, the lower temperatures were accompanied by the higher absolute humidities.

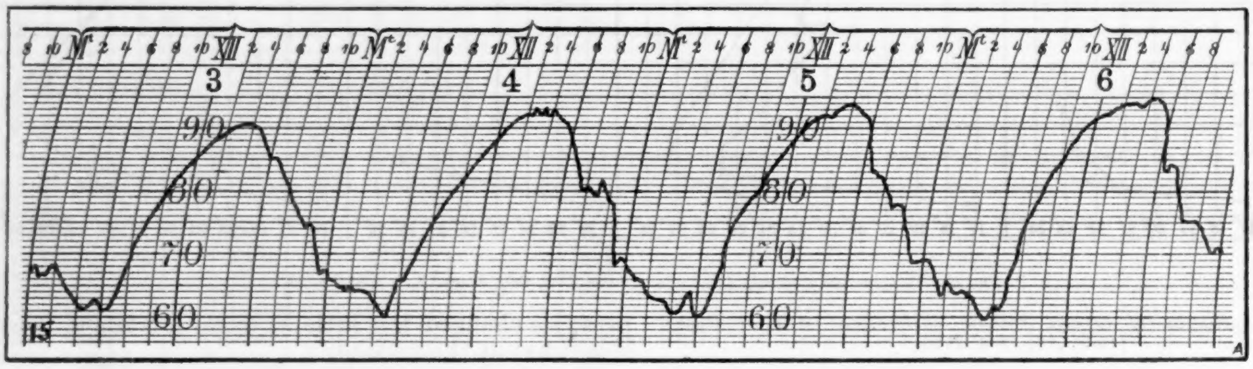

FIG. 15.—Thermograph record (°F.), at Independence, Cal., August 3–6, incl., 1913, showing fluctuations in temperature during nighttime.

TABLE 15.—*Fluctuations in surface temperature and humidity at Lone Pine, Cal., Aug. 2 and 3, 1913.*

Date.	Time.	Temperature.	Relative humidity.	Absolute humidity.
1913.	*P. m.*	*°C.*	*Per cent.*	*g/cu. m.*
Aug. 2	7:48	22.2	48	9.3
	7:51	20.6	56	9.9
	8:01	*19.4*	*64*	*10.6*
	8:45	20.0	56	9.6
	9:10	*16.7*	*75*	*10.6*
	9:21	18.7	64	10.2
	10:01	*16.7*	*75*	*10.6*
	11:00	18.3	62	9.6
	11:05	*16.4*	*77*	*10.7*
	11:48	18.9	60	9.6
Aug. 3	6:50	25.1	40	9.2
	7:40	*21.1*	*56*	*10.2*
	7:50	*19.4*	*56*	*9.3*
	8:05	20.8	45	8.1
	8:37	*19.4*	*52*	*8.6*
	9:09	21.1	42	7.7
	9:33	23.9	34	7.3
	9:43	*21.8*	*47*	*8.9*

Between 8 and 10:30 p. m. it was necessary to bring the balloon down because of southerly or southeasterly winds aloft. These winds gradually extended toward the surface and were warm and dry (Table 13). The mixing of the upper southerly and the lower northerly currents seems to account for the variations in surface temperature and humidity already referred to.

The fact that the upper southerly wind is warm and dry suggests the probability that it originates over the Mohave Desert, which is about 150 kilometers south of Lone Pine. The heating and consequent rising of air over the desert in the daytime, which gives rise to the southerly current aloft, at the same time causes the surface northerly current down the valley.

THE HORIZONTAL RAINBOW.[1]

By S. FUJIWHARA.

[Dated Central Meteorological Observatory, Tokyo, January 12, 1914.]

The so-called horizontal rainbow has been reported by several scientists. Julius von Hann observed this mysterious optical phenomenon on Lake Constance, and W. R. N. Church has seen it on Loch Lomond. F. Hashimoto observed such a rainbow (or horizontal spectrum) on Lake Suwa in central Japan on the morning of November 3, 1912. On this morning the weather was very clear. He and Count A. Tanaka were then engaged in limnological observation at the shore near Kakuyûkan. Mr. Hashimoto saw the rainbow on the water surface of the northeastern part of the lake. They at first observed the bow with their eyes at a height of 9 feet above the water level. On bringing their eyes down to the height of 6 feet the length of the bow diminished, but the colors became very distinct. By lowering their eyes the bow became clearer, and at last, at a height of a little lower than 4 feet, it vanished. At any height lower than this they could no more see the bow, but above this height the bow was seen. As the sun rose higher the bow shifted to the right and vanished from them at 11 a. m., while standing on the shore; soon they went up the stairs of an inn near by, and thence they could perceive the bow, though indistinctly. The position of the lake and features of the bow on this occasion were as shown in figure 1. About 8 a. m. on December 8, 1913, Mr. Hashimoto again observed a similar phenomenon on the same lake. At this time he was in a boat making limnological observations. In his letter to me he states the results of his observations. On the morning in question the surface temperature of the water of the lake was 8° C. and that of the air was about 3° C. He also observed a very thin haze or mist over the surface of the lake and the air was very calm. The optical conditions on December 8, 1913, are presented in figure 2, where the plane of the figure represents the surface of the lake water; OS' is the horizontal projection of the sun's ray passing through O, the position of the observer, Mr. Hashimoto. OV and OR are the limiting rays of the horizontal rainbow RV. The angle ROV has been estimated at about 3°, and the horizontal angle VOS at 38°. The violet side of the bow is indicated by OV and the red side by OR.

[1] *Revised and reprinted from* Jour. met. soc. Japan, Tokyo, March, 1914.

The formation of the horizontal rainbow seems to be not yet fully explained. One is naturally inclined to regard it as a phenomenon similar to the ordinary rainbow; but the only property they have in common is that of the spectrum colors. In all other respects they are quite different. The principal points of difference are:

1. The horizontal rainbow occurs in very clear weather and is not associated with rain.
2. The arrangement of the colors in a horizontal rainbow is radial, and not transverse [concentric circles] as in an ordinary rainbow.
3. The ordinary rainbow appears as a vertical circular arc having an angular radius of about 40° to 42°, while the horizontal bow or "ohikari" has the form of a horizontal narrow sector about 3° wide. Sometimes the horizontal sector is 15° wide, which is never the case in an ordinary rainbow.

THEORETICAL CONSIDERATIONS.

In the following is presented a physical explanation of this rare phenomenon.

Assume that two conditions prevailed in the actual case: (*a*) A thin sheet of mist formed of very small water drops lies over the water surface. This may often happen over any body of shallow water on a very calm and comparatively warm day. Lake Suwa is a shallow body of water; under strong insolation its water warms up readily and evaporation from the surface takes place rapidly. Mr. Hashimoto reports that on the morning of December 8, 1913, the temperature of surface water was 8°C. and that of the air above was about 3°C. He also observed very thin mist on the surface of the water. During the colder months vapor from the lake surface must condense into small drops at the height of but 1 or 2 meters above it. (*b*) Assume the position of the sun proper for the formation of a horizontal bow. This condition also was fulfilled in the cases under discussion.

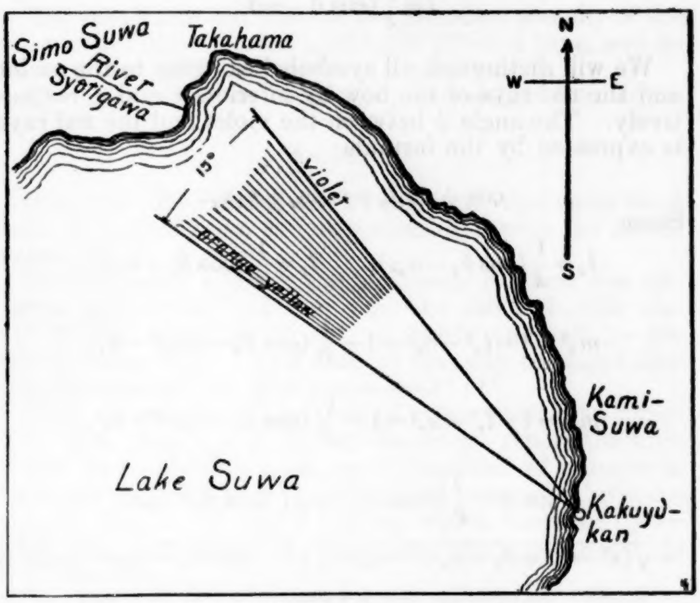

FIG. 1.—Horizontal rainbow on Lake Suwa on November 3, 1912.

Now, suppose the eye of the observer placed at the origin, O, of the rectangular coordinates x, y, z, in figure 3. Let z be taken vertically upward and y perpendicular to a ray from the sun. For the sake of simplicity, the sun's rays may be regarded as all parallel at any instant; the altitude of the sun may be designated as h, and the direction cosines of the sun's rays may be λ, μ, ν, where $\lambda = \cos h$, $\nu = -\sin h$. The equation of the sheet of mist having a height a above O, will be $z = a$.

According to the geometrical theory of the rainbow, the drops reflecting any spectrum color of the rainbow to the eye must lie in the surface of a cone whose apex is at the observer's eye, O, whose axis is parallel with the ray from the source of light, S, and whose semiapical angle is the supplement of the angle of minimum deviation for that color and for those drops. According to the new theory,[2] which considers diffraction phenomena, the magnitude of the semiapical angle of the cone is slightly different from that of the geometrical theory, and varies with the magnitude of the drops. In either case we shall designate the apical angle of the cone by θ.

The equation of the cone becomes

$$\sqrt{(x^2+y^2+z^2)}\,\cos\theta = (\lambda x + \nu z)$$

Dispersion phenomena must occur in the drops above the lake surface when the sun shines upon them. The phenomena must be observed along the curve of intersection of the semicone and the plane of the sheet of drops. The equation of the curve of intersection is

$$\sqrt{(x^2+y^2+a^2)}\,\cos\theta = (\lambda x + \nu a),$$

in the plane $z = a$.

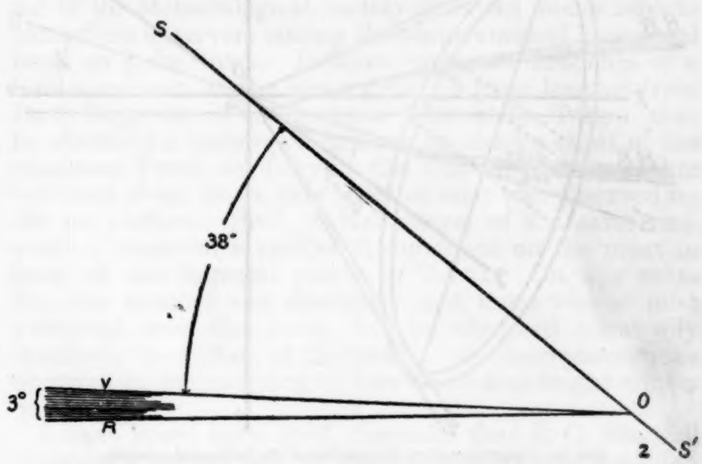

FIG. 2.—Optical circumstances favoring a horizontal rainbow on December 8, 1913.

From this equation we know

(I) The curve is (a). An ellipse, when $\cos^2\theta > \lambda^2$, $a < 0$, and the equation becomes

$$\frac{\left(x+\dfrac{a\lambda\nu}{\cos^2\theta-\lambda^2}\right)^2}{\dfrac{a^2\cos^2\theta\sin^2\theta}{(\cos^2\theta-\lambda^2)^2}}+\frac{y^2}{\dfrac{a^2\sin^2\theta}{\cos^2\theta-\lambda^2}}=1,$$

(I) (b) A single point, when $\cos^2\theta > \lambda^2$, $a = 0$, its coördinate being

$$x = 0,\; y = 0,$$

(I) (c). Vanishes when $\cos^2\theta > \lambda^2$, $a > 0$.

(II) The curve is (a). A parabola, when $\cos^2\theta = \lambda^2$, $a < 0$, and the equation becomes

$$y^2 = -2b\tan\theta\,(x + b\cot 2\theta)$$

[2] Airy, Trans. Camb. phil. soc., 1838, v. 6, p. 379, and 1848, v. 8, p. 595. Also papers by Boitel, Larmor, Mascart, L. Lorenz, Pernter, Aichi, and T. Tanakadate.

(II) (b). A straight line, when $\cos^2\theta = \lambda^2$, $a = 0$, and the equation becomes

$$y = 0.$$

(II) (c). Vanishes, when $\cos^2\theta = \lambda^2$, $a > 0$.

(III) (a), and (III) (c). The curve becomes one branch of a hyperbola, when $\lambda^2 > \cos^2\theta$, $a \gtrless 0$, and the equation is

$$\frac{\left(x - \frac{a\lambda\nu}{\lambda^2 - \cos^2\theta}\right)^2}{\frac{a^2 \cos^2\theta \sin^2\theta}{(\lambda^2 - \cos^2\theta)^2}} - \frac{y^2}{\frac{a^2 \sin^2\theta}{\lambda^2 - \cos^2\theta}} = 1$$

(III) (b). Two straight lines passing through the origin, when $\lambda^2 > \cos^2\theta$, $a = 0$, and the equations are

$$x = \pm y \frac{\cos\theta}{\sqrt{\lambda^2 - \cos^2\theta}}.$$

Thus, we see that in order to observe the horizontal rainbow it is convenient to have the eye not lower than the sheet of water drops.

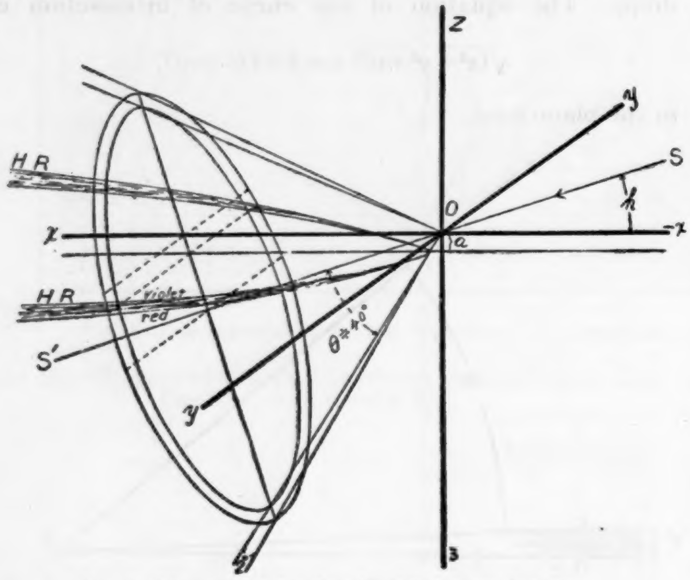

FIG. 3.—Diagrammatical explanation of the horizontal rainbow.

Suppose the eye is on a level with the sheet of drops. At sunrise, since $\lambda^2 = 1 > \cos\theta$ and $\lambda^2 - \cos^2\theta = \sin^2\theta$, the rainbow must appear in two straight lines, each making the angle θ with the ray which enters the eye of the observer. As the altitude of the sun increases λ decreases, and consequently the angle between the two straight lines becomes smaller and smaller. At the instant when $\lambda = \cos\theta$ the two coincide and at the next moment the rainbow vanishes. As the sun travels from east to west the axis of the cone shifts from left to right of the observer.

Next consider the case when the eye of the observer is above the sheet of water drops. First the horizontal rainbow is of the form of one branch of an hyperbola. Gradually the vertex approaches the observer and the aperture of the curve diminishes, its axis shifting from left to right. At the instant when $\cos^2\theta = \lambda^2$ the curve becomes a parabola and at the next moment it becomes an ellipse. Thenceforth its major and minor axes diminish, but they do not vanish unless the mist disappears. After the sun passes the meridian the dimension of the bow increases again, repeating the same changes but in the inverse order.

In order that the horizontal rainbow may be distinctly visible, the angular distribution of the drops must be somewhat dense, so that as the observer rises higher the figure becomes less distinct. For the above reason, and since the eyes of the observer are situated in general a few meters above the surface of the lake, the hyperbolic or parabolic bow must be one or two sensibly straight lines when the horizontal rainbow appears at a great distance from the observer. Since light undergoes dispersion, there must be tape-like colored bands along these two straight lines. This is why the colors in the horizontal rainbow appear radially and in the form of a band. The horizontal rainbow appears on clear days because only on clear days can there be drops with the sun shining upon them. Thus, all the principal facts are explained.

Next we will calculate the breadth of the rainbow and will find the position of the sun favorable to the actual production of a horizontal rainbow. Let l, m, n be the direction cosines of the beam from any drop near the surface of the lake to the eye. Then

$$\cos\theta = l\lambda + n\nu$$

or

$$l = \frac{1}{\lambda}(\cos\theta - n\nu)$$

We will distinguish all symbols belonging to the violet and the red rays of the bow by inferiors v and r, respectively. The angle ϕ between the violet and the red rays is expressed by the formula

$$\cos\phi = l_v l_r + m_v m_r + n_v n_r.$$

Since

$$l_v = \frac{1}{\lambda}(\cos\theta_v - n_v\nu), \qquad l_r = \frac{1}{\lambda}(\cos\theta_r - n_r\nu),$$

$$m_v^2 = 1 - l_v^2 - n_v^2 = 1 - \frac{1}{\lambda^2}(\cos\theta_v - n_v\nu)^2 - n_v^2,$$

$$m_r^2 = 1 - l_r^2 - n_r^2 = 1 - \frac{1}{\lambda^2}(\cos\theta_r - n_r\nu)^2 - n_r^2,$$

$$\cos\phi = \frac{1}{\lambda^2}\left[(\cos\theta_v - n_v\nu)(\cos\theta_r - n_r\nu) - \sqrt{\{\lambda^2 - (\cos\theta_v - n_v\lambda)^2 - n_v^2\lambda^2\}\{\lambda^2 - (\cos\theta_r - n_r\lambda)^2 - n_r^2\lambda^2\}}\right] + n_v n_r.$$

λ becomes zero when the sun is at the zenith, but this does not occur in our latitudes. If λ becomes zero, then $\cos\phi = 1$ or $\phi = 0°$.

In the actual case, since $\theta_r \doteq 42°$ and $\theta_v \doteq 40°$, and since the rays from the drops are sensibly horizontal, $n\nu$ may be neglected. Thus we may put

$$\cos\phi = \frac{1}{\lambda^2}\left[\cos\theta_r \cos\theta_v + \sqrt{(\lambda^2 - \cos^2\theta_v)(\lambda^2 - \cos^2\theta_r)}\right]. \qquad (1)$$

If $\lambda = 1$, or the sun is on the horizon,

$$\cos\phi = \cos\theta_r \cos\theta_v + \sin_r\nu \sin\theta_v,$$
$$= \cos(\theta_r - \theta_v),$$
$$\doteq \cos 2°$$

and

$$\phi \doteq 2°.$$

If $\lambda = \cos\theta_v$

$$\text{then } \cos\phi = \frac{\cos\theta_r}{\cos\theta_v}$$
$$= \cos 16° 44'$$

and

$$\phi = 16° 44'.$$

This shows that the breadth of the rainbow must be some value between 2° and 16° 44′. The values θ_r and θ_v here used are rough approximations, hence the quantities obtained only show the order of magnitude. The exact values of θ_r and θ_v vary with the magnitude of the water drops. If the drops are small the angles diminish even to the value $\theta_v = 38°$. In such a case the breadth of the bow becomes smaller than the value shown above.

Next we shall calculate the breadth of the rainbow in the actual case. The position of the observer on November 3, 1912, was

longitude 138° 7′ E. of Greenwich.
latitude 36° 3′ N.

Declination of the sun at 9, 10, and 11 a. m. was −14° 53′, −14° 54′, and −14° 55′, respectively, and the corresponding computed altitudes of the sun were

$$h_9 = 27° 45', \; h_{10} = 34° 39', \; h_{11} = 38° 29'.$$

Introducing these values in equation (1) we get

$$\phi_9 = 4° 4', \; \phi_{10} = 5° 57', \; \phi_{11} = 10° 44'.$$

The maximum altitude (at the meridian transit) of the sun on that day occurred at $11^h\, 31^m\, 27^s$ civil time, and its amount was 39° 1′ 36″.

If we put $h = 39°$ or $\lambda = \cos 39°$, then we get from equation (1)

$$\phi = 14° 0'.$$

Since the observation was a rough one, this value for ϕ must be looked upon as fairly coinciding with the actual value, that is, $\phi = 15°$.

On December 8, 1913, the horizontal rainbow was observed at 8 a. m. At that time the sun's altitude was 11° 23′ for which $\phi = 1° 28'$, or nearly one-half its observed value of 3°. At 9 a. m. of that day the sun's altitude became 19° 17′, and hence $\phi = 3° 17'$.

Thus we see that if the time of observation was somewhat later than 8 a. m. (in the observer's report the time is said to be about 8 a. m., so the number of minutes is naturally obscure), then the calculated value of ϕ becomes greater than 1° 28′, and if the true width would be somewhat less than observed, then the theory may coincide with the facts.

The angle SOV in figure 2 can be calculated. Since

$$\cos 40° = l_v \lambda + n_v \nu$$
$$= l_v \lambda,$$

hence

$$l_v = \frac{\cos 40°}{\lambda} = \frac{\cos 40°}{\cos 11° 23'} = \cos 38° 11'$$

at 8 a. m. Thus value agrees very well with the observed value 38°.

Thus there is sufficiently close agreement between theory and facts to determine the true cause of the horizontal bow. One point remains to be noticed, however. The observer tells us that on November 3 the rainbow vanished at 11 a. m. How can it vanish? There must be two explanations. The first of these is that the sheet of drops might vanish with the increase of air temperature; the second is that the drops did not dissolve but that the sun became so high that its altitude exceeded the apical angles of the cones for both the violet and the red rays. At first thought it seems likely that the altitude of the sun could not increase to a sufficient degree to cause the rainbow to vanish, because θ_v is nearly equal to 40° and the calculated maximum altitude of the sun is 39° 2′. But as before remarked, the above value of θ is a rough approximation. Sometimes when the drops are very small, e. g. of a radius less than 0.025 mm., the the value of θ may become less than 38°. Since the mist was very thin, such small drops may have existed. If so, then, when the sun reached the proper altitude, the bow would become invisible to an observer whose eyes were on a level with the sheet of drops. To one whose eyes were above the sheet of drops, however, the bow might still be visible, though it would have become somewhat indistinct. This was proved by the above given observation.

POSTSCRIPT, JULY 12, 1914.

On January 30, 1914, Mr. Katsuji Nakamura, of the Central Meteorological Observatory, Tokyo, happened to observe a horizontal rainbow in the moat of the observatory. After that, this often appeared in the morning of calm winter days. The account of this is given in the Journal of the Meteorological Society of Japan, 33d year, No. 6. He and I made observations of the angular breadth of the bow, the difference of the departures of the violet and red ends of the bow from the direction of the sun's ray passing through the observer's eye, the altitudes of the sun, etc., and found a good agreement with the theory given in the text. Since I have written about the horizontal rainbow in the Journal of the Meteorological Society of Japan, many reports came from observers stating the occurrences of horizontal bows on Lake Suwa. In some cases two branches of a bow were seen at the same time. I have learned from Prof. Nagaoka, of the Imperial University, Tokyo, that he observed a horizontal rainbow on the ice sheet of the Sinobazu Pond, in Tokyo. On that day the weather was very clear, but a thin sheet of mist was observed on the ice surface. Prof. S. Nakamura, of the same university, observed a similar phenomenon on the moat in front of the imperial palace in Tokyo. On this occasion the weather was also clear, and there was no mist perceived over the moat, but he observed some oily specks on the surface of the water. All these phenomena occurred in the morning of very calm and bright winter days.

I have heard from Prof. Nagaoka that J. C. Maxwell observed a colored bow on the frozen surface of the ditch which surrounds St. John's College, Cambridge.[3] It occurred on the 26th of January, 1870, at about noon. He measured with a sextant and found that the angular distance of the bright red of the bow from the sun's ray was 41° 50′, and that of the bright blue 40° 30′. He considered the bow to be produced by water drops on the ice surface. Bows formed by ice crystals are seen on the same side as the sun and not on the opposite side. These angles are somewhat smaller than the values for an ordinary rainbow. This fact was also found by us. The following table shows the values of the angular apertures of the bows observed in Tokyo:

Date.	Jan. 30, 1914, 9:50 a. m.		Jan. 30, 1914, 10:25 a. m.		Feb. 17, 1914, 9:44 a. m.	
	°	′	°	′	°	′
Red	41	35	42	36	41	52
Violet	38	51	39	53	40	02
Difference	2	41	2	43	1	50

Maxwell left two questions unsolved, one of which was why are the angular apertures of the horizontal bow

[3] *Maxwell.* On a bow seen on the surface of ice. Edinb. Roy. soc. proc., v. 7; also see Scientific Papers, II, p. 160.

smaller than those of the ordinary bow; the other question was that how a drop of water can lie upon ice without wetting it and losing its shape altogether. In the light of the modern science these two questions seem to be clearly answered, as shown in the text of the present paper, taking the following facts into consideration: first, the water drops are very small ones, and, second, they float in the thin stratum of air in contact with the ice surface but [they do] not lie on the surface. According to the diffraction theory of the rainbow, the angular aperture of the bow becomes small when the droplets producing the bow are very small. In many cases they are invisibly small. That the droplets are floating in air, but not lying on the surface of ice or water, can easily be seen from the fact that the bow appears on the water surface as well as on the ice surface, and also that it occurs always on calm and bright mornings in the cold season. The following fact also supports the idea: On the morning of March 17 we observed a horizontal bow in the moat of our observatory. At about 9:20 a. m. we saw wind that came over the water surface from the west. The bow became faint when the head of ripples arrived at the bow, and gradually it vanished away as the wind became stronger.

From early times people in Suwa have been well acquainted with the phenomenon. They call the phenomenon "Ohikari" which means literally a holy shine, and take it to be a foretoken of the coming change of the weather. Indeed, many times when we observed a horizontal rainbow in the moat of this observatory we experienced rain or storm one or two days after. The reason of this, in my opinion, must be as follows: On the Pacific side of Japan the weather in winter is generally clear and the northwesterly monsoon prevails every day. On the appearing of a cyclone in the west the monsoon is disturbed by the easterly or southeasterly winds flowing into the cyclonic center. Hence there then prevails a calm. Considering the atmospheric pressure, this calm corresponds to the high pressure over Japan, which is followed by a cyclone. Such a calm is always favorable for the formation of a horizontal rainbow. Thus the calm, as well as the horizontal rainbow, are in many cases the foretokens of the coming cyclone.

OBSERVATIONS OF HORIZONTAL RAINBOWS.[1]

By KATSUJI NAKAMURA.

[Dated Central Meteorological Observatory, Tokyo.]

The author of the present note had favorable opportunities of observing the horizontal rainbow in the moat near the entrance of Central Meteorological Observatory, which is situated in the compound of the old castle of Tokyo. The following lines contain short descriptions of the phenomena and of the weather conditions that then prevailed:

1. Horizontal rainbow on January 30, 1914.—On the morning of January 30, 1914, a greater part of the surface of the moat was covered with a thin coating of ice. The sky was cloudless, and the air was so calm that we scarcely felt even the quivering of the leaves of trees and grasses. We observed the rainbow from 9:30 a. m. until 10:40 a. m. before the ice began to melt.

When we stood at A (a point on the bridge) in figure 1, turning our back to the sun, we saw the rainbow on the left and downward as at DH, but its colors were not distinct. Then as we moved from A toward B, C, . . . the far side of the rainbow appeared to shift from D toward R and E, . . . and its colors gradually became vivid.

As seen from F, a point higher than A, B, M, C, etc., we also saw the rainbow toward KF, but its colors were not so distinct as when seen from the other places, A, B, etc. At G, one of the highest places, we saw that the bow was lying toward LG, its color becoming fainter. But when standing at O, a point having an equal height with G, we could not see the bow.

From what we have stated above we see that G is one of the limits of visibility of the rainbow on this morning.

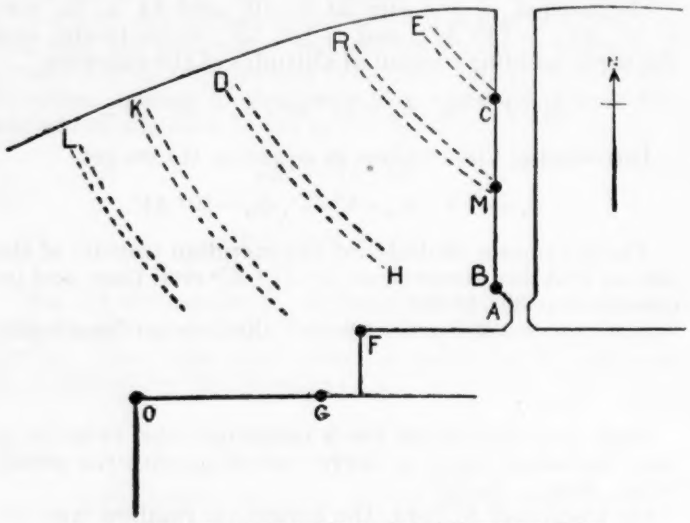

FIG. 1.—Plan of moat of Central Meteorological Observatory, Tokyo.

On the ice surface the rainbow was more clearly visible than on the water.

We give here the widths of the rainbow that Dr. S. Fujiwhara observed with a sextant:

9:50 a. m.:	°	′	10:25 a. m.:	°	′
Red	41	35	Red	42	36
Violet	38	54	Violet	39	53
Width	2	41	Width	2	43

Of course these values are rough approximations.

2. The rainbow observed on February 17, 1914.—On this morning upper clouds thinly covered the sun and the sky and it was so calm that it grew rather hazy all around and there was no ice in the moat.

We observed the rainbow, on this morning also, at the same places, A, B, M, C, etc., in figure 1. Its color as seen from B was more vivid than when seen from A, and clearer as seen from M than from B. When seen from C it was not so clear as when seen from M, that is to say, from M the bow was clearer than from other points and the color became thin by standing away from the place M. Besides this, even on the same zone MR, the color of the bow at R was very clear and became gradually faint toward M.

We give here the results of Dr. Fujiwhara's measurements:

9:44 a. m.:	°	′
Red	41	52
Violet	40	02
Width	1	50

[1] *Reprinted from* Jour. met'l soc., Japan, Tokyo. 33rd year. June, 1914, pp. 25-28.

At 10:30 a. m. the sun's altitude was about 34° 30′. The results of the meteorological observations made on these mornings in Tokyo are as follows:

Atmospheric condition on January 30 and February 17, 1914.

January 30, 1914.

Elements.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	Noon.
Pressure (mm.)	756.8	756.9	756.9	756.9	756.8	757.2	757.7	757.9	758.0	758.0	757.6	756.6
Air temperature (° C.)	−1.6	−1.8	−1.3	−1.8	−2.4	−2.5	−2.5	0.2	2.9	5.9	7.4	9.0
Relative humidity (per cent)	90	90	85	85	87	80	82	70	65	53	51	44
Vapor pressure (mm.)	3.7	3.6	3.5	3.4	3.3	3.0	3.1	3.3	3.6	3.7	3.9	3.8
Wind direction	SSE.	SSE.	W.	W.	W.	W.	W.	W.	W.	W.	NNW.	NE.
Wind velocity (m/s)	1.1	1.3	2.4	2.0	1.5	1.5	1.3	1.6	1.5	1.5	2.4	2.2

February 17, 1914.

Elements.	1 a. m.	2 a. m.	3 a. m.	4 a. m.	5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	Noon.
Pressure (mm.)	766.4	766.4	766.2	766.2	766.7	766.5	766.6	766.7	766.7	766.4	766.1	765.5
Air temperature (° C.)	2.4	2.6	2.8	2.1	0.6	−0.4	−0.2	3.0	5.2	7.9	11.6	11.2
Relative humidity (per cent)	98	98	96	98	96	95	95	94	79	67	60	60
Vapor pressure (mm.)	5.3	5.4	5.4	5.2	4.6	4.2	4.3	5.3	5.2	5.3	6.1	6.2
Wind direction	NE.	NE.	N.	N.	N.	N.	N.	N.	N.	N.	NNW.	NNW.
Wind velocity (m/s)	1.5	1.5	1.1	1.3	1.3	1.3	1.3	0.8	1.5	0.8	1.8	2.8

In the above tables the air pressure is not reduced to sea level, but only to freezing point.

3. *Horizontal rainbow on March 17, 1914.*—On this morning the sky was so clear that we observed not a single speck of clouds and the air was comparatively calm. At the surface of the same moat we observed a horizontal rainbow from 8:30 a. m. until 9:20 a. m. But on account of ripples on the surface of the moat we could observe no more after 9:20 a. m.

In the narrower part of the moat, which was nearer to [it ?] the north side of the bow was very distinctly visible. We could not measure the width of the bow with much accuracy, but the value estimated was about 3°.

In conclusion, the author wishes to express his hearty thanks to Dr. T. Okada for his kind guidance.

THE HALOS OF NOVEMBER 1 AND 2, 1913.

By Dr. LOUIS BESSON.

[Dated: Observatoire de Montsouris, Paris, April 21, 1914. Translated by C. Fitzhugh Talman, Professor of Meteorology.]

Some remarkable optical phenomena of the class of halos and parhelia were seen in the eastern half of the United States on November 1 and 2, 1913. On the 1st, there was observed at many places the halo of 22° radius, in some cases brilliant and accompanied by the parhelia pertaining to it, but the phenomenon appears to have attained abnormal complexity only in a rather limited region, comprising southwestern Missouri and extreme northeastern Arkansas. At Springfield, Mo., according to Mr. J. S. Hazen, Local Forecaster, "this unusual and remarkable phenomenon excited a great deal of interest and comment among all classes and the office had more than a hundred calls during the day concerning the phenomenon."

The following day, optical phenomena no less remarkable, and of a very similar aspect, were again observed, but this time at a great distance to the eastward, in the states of Virginia, West Virginia, and Maryland. In a letter to the editor of the Scientific American, Dr. E. C. L. Miller, of the University College of Medicine at Richmond, Va., says that the phenomenon was very complex and striking at that place. It was doubtless equally so, he adds, "in a considerable area, for several inquiries were received by the railway companies from their station agents out on their lines as to the cause of the phenomena."

From inquiries made by Prof. J. Warren Smith at Columbus, it appears that in Ohio several persons observed brilliant and persistent halos on the 1st and 2d, as well as parhelia and other less common appearances, but that the phenomenon was less generally observed and probably less well developed in that region.

METEOROLOGICAL CONDITIONS ACCOMPANYING THE PHENOMENA.

Brilliant halos often precede or accompany atmospheric disturbances. Those of November 1 and 2, however, were produced under typically anticyclonic conditions, and were not followed by bad weather. A center of high pressure was over Iowa on October 31, over Indiana, November 1, and over West Virginia, November 2. Not much information is at hand in regard to the movement of the ice clouds in which the optical phenomena were produced. At Springfield, at 10:30 a. m. of the 1st, the clouds were of the cirro-stratus type, and were moving from the northwest. At 11:30 their appearance was that of alto-stratus, moving from the west, and about 3 p. m. they became stratus, from the same direction. This progressive descent of the clouds leads Mr. Hazen to say that "the downward movement of the ice particles, from which the halo resulted, was evidently large," and that "it is probably true that ice particles, which may result in halos, have a greater or less downward movement, and it is suggested that the more complex forms of halo may be due to large ice particles and consequently greater downward movement or velocity." This opinion is entirely in accord with that which I expressed in 1909 in my thesis "Sur la théorie des halos,"[1] in consequence of a large number of similar observations.

HALOS OF NOVEMBER 1.

Mr. J. S. Hazen, Local Forecaster, Weather Bureau, has furnished a detailed description and a drawing of the phenomenon observed at Springfield, Mo. This drawing, reproduced in figure 1, is a combination of three different sketches made during the rather long duration of the halo; it does not, therefore, relate to a definite time and elevation of the sun. The part of the phenomenon which attracted most attention was a wide ring, *A*, half a degree

[1] Annales de l'observatoire de Montsouris, 1909, 10: 161.

in width, passing through the sun and running around the sky parallel to the horizon (parhelic circle). This was visible from 11 a. m. to 1 p. m. At times, about noon, "portions of this circle shone out with dazzling white light, from an apparently clear sky." Around the sun were seen the halo of 22°, *H*, and the circumscribed halo, *D*, both complete, colored, and "of unusual brilliance." The halo *H* is in reality a circle, and the halo *D* a sort of ellipse, but, in consequence of an illusion, of which many instances have been recorded, they were mistaken for two intersecting circles, as shown in the drawing. Mr. Hazen notes a remarkable extension of the prismatic colors at *a* and *b*, inside the space bounded by dotted lines in the drawing. Besides the circumscribed halo, a second colored arc, *G*, was tangent to the halo of 22° at its lowest point. The parhelia, *P*, *P*, described as brilliant, are shown in the drawing outside the circumscribed halo; normally they should have been inside, since the altitude of the sun did not exceed 32° 24′. A white light-pillar, *E*, marked the vertical diameter of the halo of 22°. The upper half of the halo of 46°, *C*, was visible. The parhelic circle showed, at *x*, *y*, *z*, spots of greater illumination, of which the first, *x*, was the anthelion, and the other two, *y* and *z*, were paranthelia, which the drawing places 45° in azimuth from the anthelion. One might assume these to be the ordinary paranthelia, the vertical distance of which from the anthelion is 60°, but in that case the small arcs which pass through them, and which appear to belong to a circle having its center at the anthelion, would constitute something entirely new. From the anthelion proceeded two white arcs, *B*, *B*, directed obliquely toward the region of the sun. This is a rare and interesting appearance, known under the name of "oblique arcs of the anthelion." We shall return to this subject later.

In reply to a request for further information, the observer states that "the spots, *x*, *y*, *z*, were not distinctive in their characteristics and had more the appearance of a diffused tail to a comet than a distinct arc of a circle, though it was assumed at the time that there were probably such arcs at *y* and *x*, and a convex segment at *x*. There was a faint suggestion of color, through smoked glasses, at *y* and *z*, but none at *x*." The arcs, *B*, *B*, "were not observed until about noon and only for a short time." In his description of the phenomenon, Mr. Hazen speaks of a "white spot in the southwest" which is not shown in the drawing.

At Galena, Mo., the phenomenon was visible between 11 a. m. and noon, and Mr. H. McGrew made a drawing of it, which has been forwarded by Mr. Hazen. There is here seen (fig. 2) the halo of 22°, with a bright spot at the top; the parhelic circle ending at the halo; the two ordinary parhelia (which are shown in the drawing in the circumference of the halo, from which they should have been 3 to 5 degrees distant); two paranthelia, 39° from the anthelion, which is here only shown as the point of intersection of two oblique arcs, shorter than those seen at Springfield; finally, traces of a vertical light-pillar inside the halo of 22°. Elevation of the sun, 37° to 39°.

At Bentonville, Ark., according to Mr. Parker, Assistant Observer, U. S. Weather Bureau, the phenomenon was visible from 8 a. m. to 11 a. m. It was "almost exactly the same as seen at Danzig in 1661, excepting that there was no trace of a mock sun at the western extremity of the horizontal circle." (This refers, no doubt, to the anthelion.) "At times the horizontal circle was complete, but mostly portions of it were obscured by thin clouds. The upper arc above the sun was remarkably bright." Mr. Parker's sketch, reproduced in figure 3, is intended to represent the appearance of the phenomenon at 10:30 a. m., but I think that certain particulars were really seen earlier, and no longer existed at that time. Thus the very brilliant tangent arc, at the summit of the halo of 46°, can hardly be other than the circumzenithal arc, the appearance of which is normally impossible when the sun is 35° above the horizon, which was its altitude at 10:30 a. m. The paranthelia are situated in their theoretical positions, 120° from the sun on the parhelic circle. The western one, which was not obscured by lower clouds, was brilliant. Both of them are crossed by arcs which, in my opinion, very probably belong to the halo of 90°, known as the "halo of Hevelius." In fact, with a solar elevation of 35°, the halo of 90° radius cuts the parhelic circle almost exactly at 120° from the sun. Lastly, there are seen in the drawing parhelia of 46°, described as "bright," and shown exactly on the corresponding halo.

At Bentonville, Mr. E. H. Jacobs made, apparently with great care, four drawings of the phenomenon; viz, at 8 a. m., between 8:30 and 9 a. m., at 9:30 a. m., and at 11:30 a. m. Solar elevations: 14°, 19° to 24°, 28°, and 39°. In two of these drawings (figs. 4 and 6) are seen the parhelia of 46° without the corresponding halo, an interesting observation, confirming the real and independent existence of these parhelia, which has long been a matter of doubt. Between 8:30 and 9 a. m., with solar elevation between 19° and 24°, the halo of 46° was visible. In the drawing (fig. 5) it passes exactly through the parhelia. At the summit of this same halo is seen the circumzenithal arc, the red portion of which is shown in coincidence with the blue of the halo.[2] This lack of tangency of the bands of corresponding color in the two luminous arcs is real, and increases in proportion as the sun moves away, either upward or downward, from the altitude of 22°, at which there is exact tangency between the arcs. With a solar elevation of from 19° to 24°, the maximum departure from tangency is only 0° 19′, and would be quite difficult to observe. The first two drawings show in the southwest, 90° from the sun in azimuth, parhelia crossed by an arc of the halo of Hevelius, the halo being described as "white and bright." On the last drawing (fig. 7), made at 11:30 a. m., are seen only, in the north, an arc of the parhelic circle, and, 13° (?) below, a parallel arc, "very dim," which is doubtless to be classed among the phenomena which Bravais has termed "extraordinary parhelic circles."

At Neosho, Mo., between 8:30 and 10 a. m., Mr. H. G. Geyer observed the halo of 22° and its upper tangent arc, both brilliantly colored, the ordinary parhelia, an incomplete parhelic circle, a "dog" in the north on this circle, "at right angles to the sun" (paranthelion of 90°), and "in the west another bright spot, which would be on a continuation of the bright streak" (probably the anthelion); finally, "nearly overhead, an arc of about 30°" (doubtless the circumzenithal arc, or the upper part of the halo of 46°).

HALOS OF NOVEMBER 2.

Dr. E. C. L. Miller observed the phenomenon at Richmond, Va., where it was particularly well developed. He furnished to the Scientific American a careful drawing (fig. 8) and a good description, as follows: "I first noticed the phenomena about noon and they remained visible several hours. The most marked object was a large circle about 30 degrees above and concentric with the horizon. It was white and about the width of the full moon. On this circle there were four bright chromatic nodes marked

[2] The original drawing is tinted to show this.

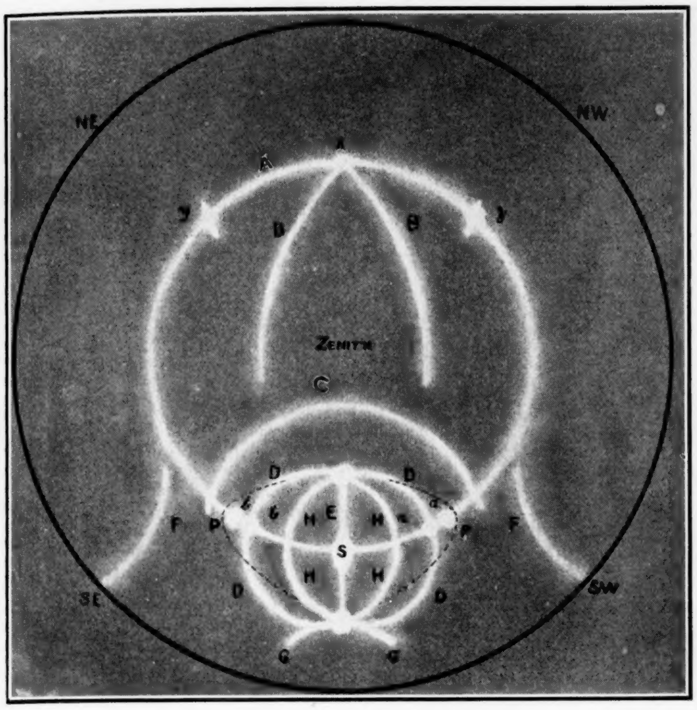

FIG. 1.—Composite drawing of halos observed at Springfield, Mo., Nov. 1, 1913, by J. S. Hazen. (No definite time or solar altitude.)

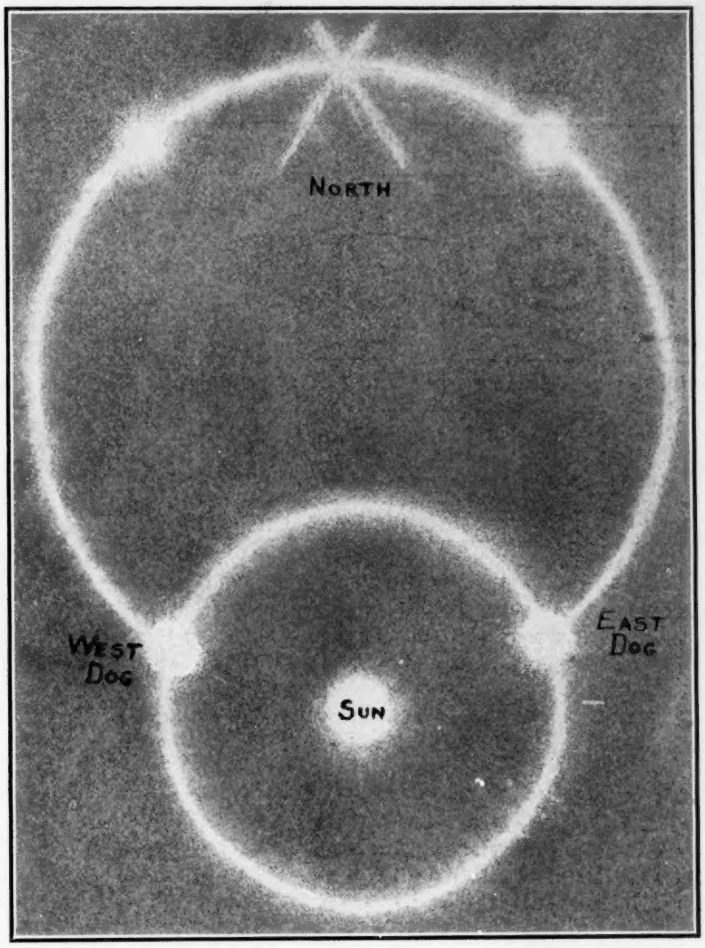

FIG 2.—Halo seen at Galena, Mo., Nov. 1, 1913, by H. McGrew. (Time: 11 a. m. to noon; solar altitude: 37°-39°.)

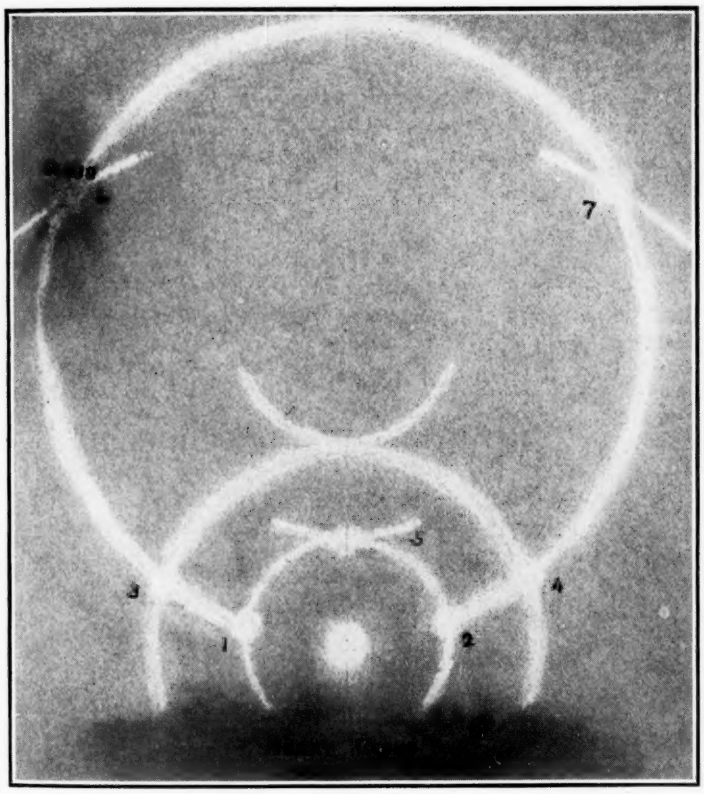

FIG. 3.—Halo seen at Bentonville, Ark., by Orin Parker on Nov. 1, 1913. (Time: 10:30 a. m. [?].)

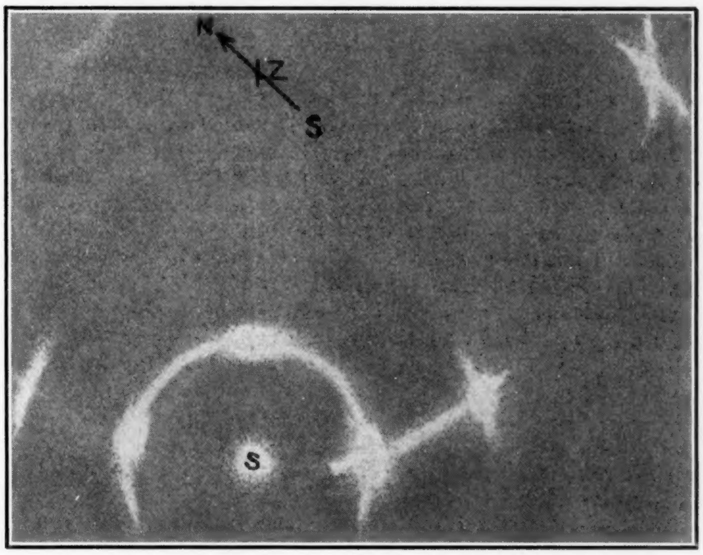

FIG. 4.—Halo seen by E. H. Jacobs at Bentonville, Ark., Nov. 1, 1913. (Time: 8 a. m.)

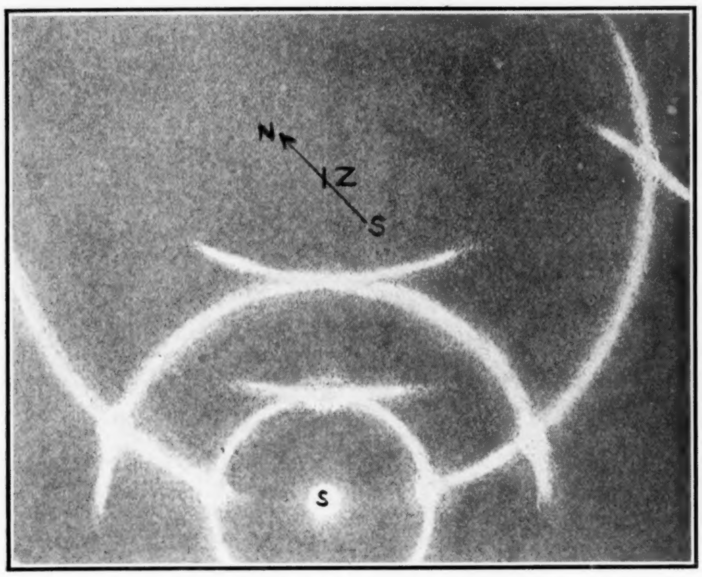

FIG. 5.—Later stage of figure 4 (8:20-9 a. m.).

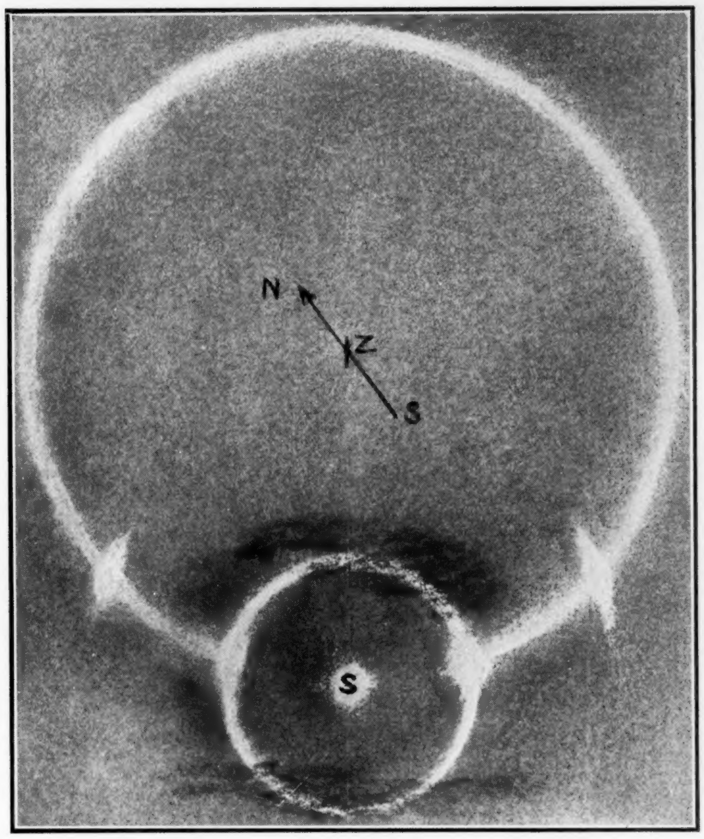

FIG. 6.—Later stage of figure 4 (9:30 a. m.).

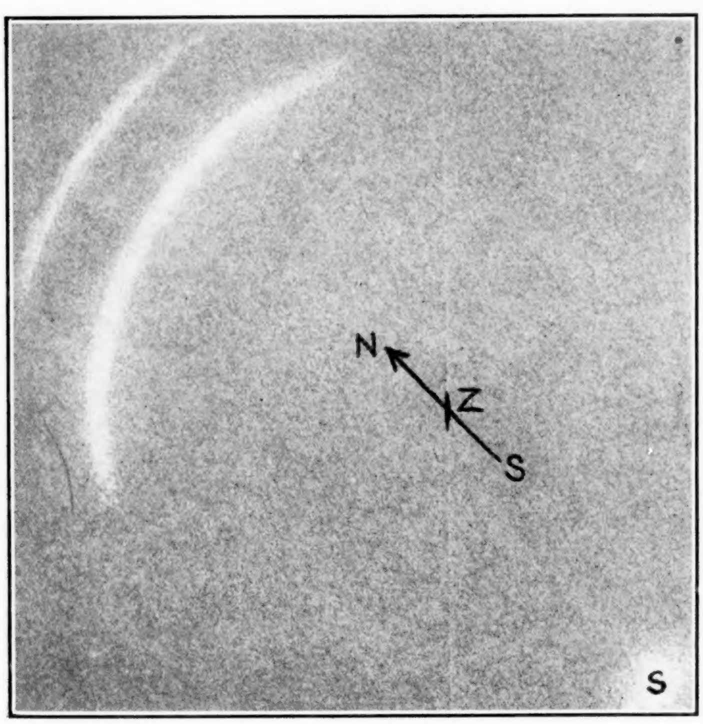

FIG. 7.—Later stage of figure 4 (11:30 a. m.).

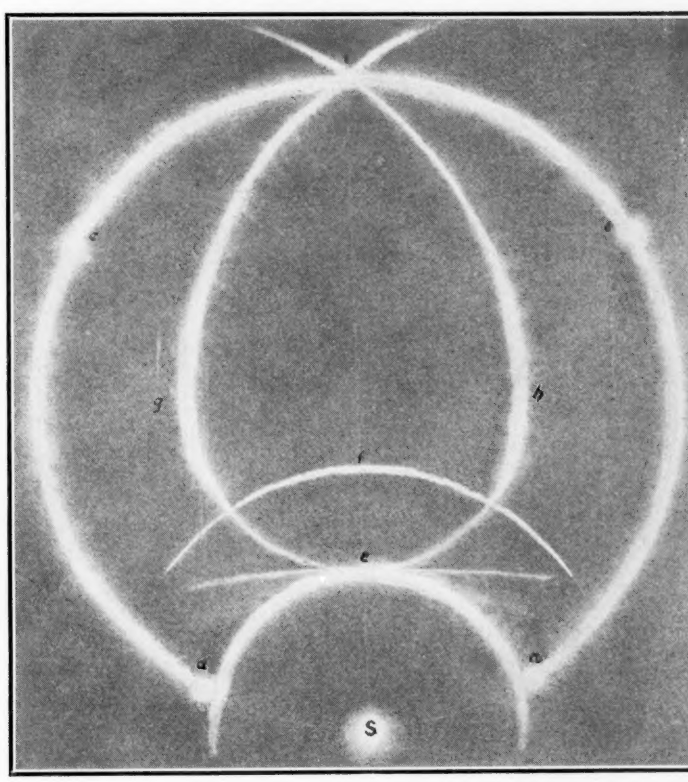

FIG. 8.—Halo observed at Richmond, Va., on Nov. 2, 1913, from noon onward for several hours, by Dr. E. C. L. Miller. (Redrawn from "Scientific American.")

on the accompanying drawing *a*, *b*, *c*, *d*. About the sun there was a marked but not unusual halo strongly chromatic at the point *e*, and gradually fading away toward each side as shown. There was a second concentric circle at *f* also chromatic. From the point *e* tangents extended out on each side as shown. Perhaps the most unusual part of the picture were the lines *ig* and *ih*. They were white, about the same width as the large circle and very clearly seen from *i* to *g* and *h*. Beyond *g* and *h* they became very faint but seemed to curve in to the point *e* as shown. On the attached sketch *s* represents the sun and *o* the zenith * * *.

"* * * The day was beautiful, an ideal autumn day; cool and clear with a slight haze in the air and a bit of herring-bone effect in the sky at times. There were no clouds except very low down and the geometrical designs traced in the sky were very striking. With some crude instruments Dr. Hopkins and I measured the angles as best we could and the drawing is fairly accurate."

In this drawing we recognize the halo of 22° and its upper tangent arc; ordinary parhelia, *a*, *d*, a little outside the halo, which is according to rule; the upper part of a halo of 46°, *f*; the parhelic circle, with the paranthelia of 120°, *b*, *c*, situated within a degree or so of their theoretical position; and, finally, a pair of oblique arcs of the anthelion, *ig* and *ih*, which seem to come together again at the summit of the halo of 22°. No anthelion.

At the Local Office of the Weather Bureau in Richmond, Mr. E. A. Evans, Section Director, observed only the parhelic circle, the ordinary parhelia with lateral portions of the halo of 22°, and paranthelia (of 120° ?), which appear to have been crossed by arcs presenting "faint intermittent red to blue colors" and whose center would appear, from the observer's sketch, to be on the side of the sky opposite the sun. This would be somewhat analogous to what was observed the previous day at Springfield.

Six miles north of Richmond, Dr. E. G. Williams made a sketch of the phenomenon at 1:15 p. m., in which are seen the halo of 22°, the ordinary parhelia, the parhelic circle, and, in the north, on this circle, two spots of white light. From the more easterly of these radiate upward two almost straight streaks of light, marked "rainbow." These might perhaps have been the anthelion with its oblique arcs, the positions of which in the sky not having been very accurately estimated. In this case, the second spot of light would be the western paranthelion of 120°, which might have been the only one visible. According to this hypothesis, which appears to me to be the most probable, the oblique arcs of the anthelion must have been colored, if this interpretation may be drawn from term "rainbow," by which the observer describes them.

At Warrenton, Va., according to Miss Isabel Gaskins, the halo was not so completely developed. She observed only the halo of 22°, with a short upper tangent arc; the upper quarter of the halo of 46°, and the circumzenithal arc, both of the latter very brilliant; the ordinary parhelia; and, lastly, part of the parhelic circle, commencing at the western parhelion and terminating in the east by a "sun dog" (paranthelion of 120°).

At Dale Enterprise, Va., Mr. L. J. Heatwole made the sketch of the phenomenon shown in figure 9. The largest of the three circles, central at the sun, is undoubtedly the halo of 46°. The two others appear to be the limits of the halo of 22°, which must have appeared very broad. The elliptical appendages of the intermediate circle were probably parhelia. The oblique arcs of the anthelion are shown in the form of an ellipse, appearing to have its second vertex about at the upper point of the halo of 22°. These arcs were "light yellow," while the parhelic circle was "snowy white." Mr. Heatwole also sends a cutting from the Pendleton Times of Franklin, W. Va., containing a description of the same phenomenon, observed about noon. In this description we note the following passage, according to which the oblique arcs came together at the sun: "Inside this circle" (the parhelic circle) "was a pointed elliptic figure, formed by similar white clouds, with the sun as its starting point, extending inside and to the northern rim of the large circle."

At Philippi, W. Va., Prof. J. D. Dadisman saw halos of 22° and 46°, with their parhelia, and the complete parhelic circle; also, opposite the sun, a sort of rainbow with paranthelia at the point where it met the parhelic circle; a tanget arc exterior to the latter at the position of the 'anthelion (oblique arcs of the anthelion ?); and, lastly, a 'broad, pale straight line of light" crossing the sky from east to west and passing through the zenith.

At Elkins, W. Va., the aspect of the phenomenon, opposite the sun, appears to have been the same. Mr. Howell, Assistant Observer, Weather Bureau, observed, from 12:05 to 12:58 p. m., the parhelic circle "of bright color, resembling cirrus clouds, brightest opposite the sun. * * * Mock suns were observed in the northeast and in the northwest, where the arc of a secondary halo intersected the primary one. * * * The arc of the secondary ring was less bright than the primary ring, and rainbow tints were not observed."

At Staunton, Va., the phenomenon presented a rather different aspect. Mr. J. C. Darnall made a drawing of it, in colors, at 1 p. m.; this is reproduced schematically in figure 10, where *h* is the halo of 22°; *c*, the parhelic circle, represented as prismatically colored (?); *p*, a parhelion of 22°; *p'*, another colored parhelion (of 46° ?); *A*, the infralateral arc of the halo of 46°, which was brilliantly colored.

At Baltimore, Md., the same infralateral arc was visible from 2 to 4 o'clock, and was very bright. Generally taken for a rainbow, it was widely noticed by the people, while the other parts of the halo passed unobserved. At Takoma Park, Md., Mr. L. M. Mooers, Cooperative Observer, saw only the parhelia, the summit of the halo of 22°, also in the form of a parhelion, and fragments of the halo of 46°.

At Braehead, near Fredericksburg, Va., according to a sketch made at 2 o'clock or a little later, by Mr. S. G. Howison, the phenomenon included the halo of 22°, the ordinary parhelia, the halo of 46°, the circumzenithal arc, and a luminous cross limited by the halo of 22°.

At Washington, D. C., Mr. W. E. Hurd, assistant at the observatory of the Weather Bureau, observed, at 4 p. m., the same phenomena, without the cross, but with the upper tangent arc of the halo of 22°. Prior to 4 p. m. only the ordinary halo and the parhelia had been visible.

BRIEF EXPLANATION OF THE OBSERVED PHENOMENA.

The luminous phenomena that we have just described were produced by the reflection and refraction of light from the sun by lofty clouds consisting of ice crystals. The greater part of these phenomena can be explained in a detailed manner, with a high degree of certainty. For others the theory generally accepted is still incomplete

or doubtful. Lastly, certain others, very rare and ill-defined, thus far escape any precise explanation. In nearly all known forms of ice crystals are found faces which meet at angles of 60° or 90°. The refraction of light in these prisms gives a maximum luminosity at 22° or 46° from the sun in all directions. Such is the explanation of the halos of 22° and of 46°.

In order to explain the other phenomena, it is necessary to assume ice crystals of a particular form, oriented in a definite manner by the resistance of the air opposed to their fall. Ice crystals often have the form of elongated right hexagonal prisms. In this case they fall horizontally, as shown in figure 11, and we may perfectly explain the ordinary tangent arcs of the halo of 22°, as well as the circumscribed elliptical halo, by the refraction of the solar rays which enter by a face, m^1, and emerge by a face, m^3, constituting with the former a prism of 60°, with horizontal edge. Moreover, the refraction of the rays which enter by a vertical base, a, and emerge by a lateral face, m, explains the infralateral arcs of the halo of 46° (arcs F F, of fig. 1). If the rays enter by a face, m, and emerge by a base, we have the supralateral arcs, which appear not to have been seen on Novem ber 1 and 2.

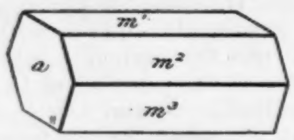

FIG. 11.—Elongated right hexagonal prism of ice, in horizontal position. (Much enlarged.)

Other phenomena are produced by hexagonal prisms oriented vertically. To fulfill these conditions it is necessary that the prisms present, at one of their extremities, a projecting plate, which plays the rôle of a parachute. Among the observed forms, that represented in figure 12 appears to be the most effective. The refraction of the rays which enter by a face, m, and emerge by a face, m^3, gives rise to the ordinary parhelia of 22°. Those which enter by the upper face and emerge by a lateral face, m, produce the circumzenithal arc (observed by Mr. Jacobs at Bentonville, fig. 5). The two forms of ice crystals just mentioned, those which we shall describe presently, and many others, present vertical faces. The simple reflection of the solar light on these faces gives us the parhelic circle. Vertical light-pillars passing through the sun are explained by multiple reflections on lamellar crystals, oscillating round the horizontal position.

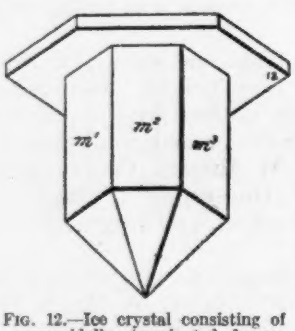

FIG. 12.—Ice crystal consisting of pyramidally terminated hexagonal prism attached to a tabular prism which acts as a parachute when the combination is falling through the air.

Now we come to phenomena whose explanation remains hypothetical. The anthelion can hardly be formed except by double reflection on faces making an angle between them of 90°. Figure 13 shows one of the possible modes of its production. For the paranthelia of 120°, the vertical faces must form an angle of 60°, or of 120°, as in figure 14. No forms of ice crystals now known furnish an explanation of the white paranthelia seen at 90° from the sun, nor of the halo of Hevelius, which is associated with them (observed by Mr. Jacobs at Bentonville, figs. 4 and 5). In the assemblages of prisms such as are shown in figures 13 and 14, the refraction of the rays which enter by a vertical face and emerge by another vertical face, making with the former an angle of 90°, might be the cause of the parhelia of 46° (observed by Mr. Jacobs at Bentonville, fig. 4). In order to explain the extraordinary tangent arcs at the lower point of the halo of 22°, such as the arc GG of the Springfield observation, figure 1, there has been invoked, without much success, the refraction of rays entering by a vertical face, m (fig. 12), and emerging by the opposite face of the lower pyramid. We have still to discuss in some detail a last form of halo, which is for several reasons the most interesting of all those observed on November 1 and 2.

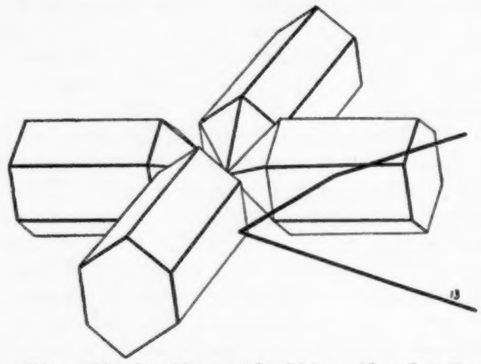

FIG. 13.—A possible combination of ice crystals which would produce the anthelion, the parhelia of 46°, etc.

The oblique arcs of the anthelion.

This is a very rare phenomenon, and its appearance in the present case on two successive days over the same region of the globe is truly astonishing. In 1850, when Bravais published his memorable works on halos, only 13 observations of this phenomenon were known. Since that time the number has been increased by 4, the last having been that observed by Brentano, at Ede, Holland, in 1900. Bravais proposed a very plausible and interesting explanation, as follows: Ice crystals often present on their faces parallel striæ. The arcs in question might be due to the dispersion of light by striæ of this nature occurring on the faces encountered by the rays which produce the anthelion. They would be arcs of small circles of the celestial sphere. The centers of these circles would remain at a constant distance from the zenith, but would shift in azimuth according to the altitude of the sun. Unfortunately, the observations do not agree well with this theory, with respect to the trajectories of the arcs in the sky. Among the data suitable for determining the trajectories, those which may be especially noted, are:

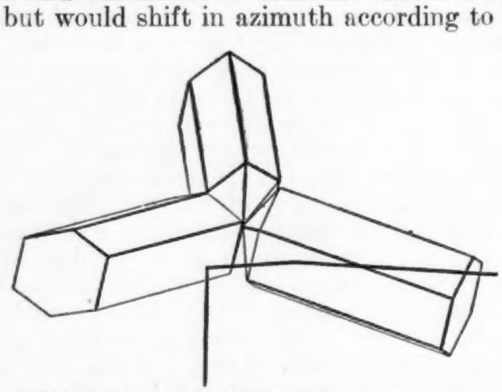

FIG. 14.—A possible combination of ice crystals which would produce the paranthelia of 120°, parhelia of 46°, etc.

1. The inclination of the arcs to the horizon, or the angle which they make with each other at their point of intersection at the anthelion.
2. The radius of curvature of the arcs.

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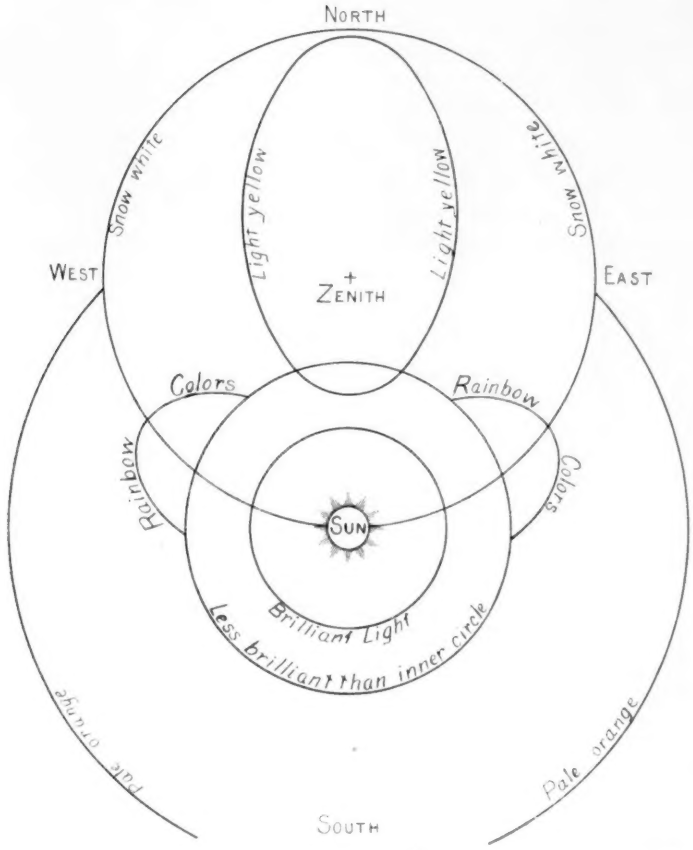

FIG. 9.—Halo observed at Dale Enterprise Va. ,by Mr. L. J. Heatwole, on Nov. 2, 1913.

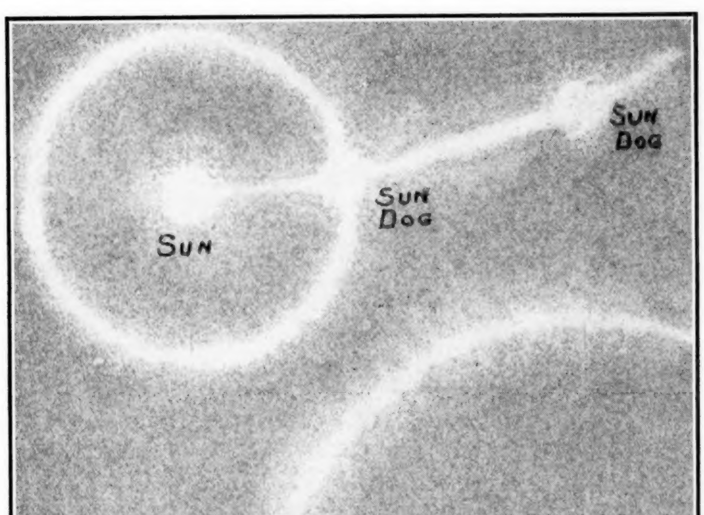

FIG. 10.—Halo observed at Staunton, Va., at 1 p. m. on Nov. 2, 1913, by J. C. Darnell.

3. The shortest distance of the arcs from the zenith.
4. The position of their second point of meeting on the side toward the sun.

The first element is difficult for the observer to determine, on account of the curvature of the arcs, and should be interpreted with caution. The second is no less difficult to determine, when the arcs are short. The third and fourth can be determined only when the arcs are of great length, but constitute much more definite criteria.

Let us consider especially the last. Before 1913 the arcs had been observed in 7 cases prolonged as far as their second meeting point, which in 4 or 5 cases had been found to be exactly at the sun. Now, according to Bravais's hypothesis, this meeting point could not coincide with the sun unless the latter were at the horizon, and it must have been far above the horizon in all the cases referred to.

The observations made in the United States on November 1 and 2, 1913, furnish some new information. From the drawings of Dr. Miller at Richmond, of Mr. Hazen at Springfield, of Mr. McGrew at Galena, and of Mr. Heatwole at Dale Enterprise, certain approximate measurements can be made, which it will be interesting to compare with the indications furnished by the theory. The solar altitude calculated from the hour of observation was between 37° and 38° in 4 cases.

Angle between the arcs.—Theoretical value, 101°-102°; Richmond, 106°; Springfield, 95°; Dale Enterprise, 180° (?); Galena, 47°.

Radius of curvature.—Mr. Hazen estimates that the arcs seen at Springfield were arcs of circles "of greater diameter than the circle parallel to the horizon." This observation is not in accordance with the theory, for the radius of the parhelic circle must have been 52° and that of the oblique arcs should have been, theoretically, 45°.

Minimum zenith distance.—Theoretical value, 15°-16°; Richmond, 27°; Springfield, 26°; Dale Enterprise, 20° (?).

Zenith distance of the second meeting point of arcs.—Theoretical value, 65°; Richmond, 59°; Dale Enterprise, 64° (?).

In the drawing of Dr. Miller, of Richmond, it is noted that the part of the arc situated on the side toward the sun had a greater curvature and a less intensity than the rest. One might inquire whether this part of the curve was not really an extraordinary tangent arc at the summit of the halo of 22°, fortuitously joining the oblique arcs and appearing to be a prolongation of them. On the other hand, it is noted that at Franklin, W. Va., these arcs appeared to meet at the sun.

In short, it is not possible to draw very definite conclusions from these observations. It is greatly to be desired that whenever the oblique arcs of the anthelion are again seen they should be subjected to exact angular measurements, and the same may be said of such other rare phenomena as the paranthelia of 90°, the halo of Hevelius, the parhelia of 46°, etc.

ADDITIONAL REPORTS.

Peoria, Ill.—A solar halo was observed on November 1, 1913, about 4:25 p. m. It was the usual 22-degree circle without marked brilliance or other unusual feature, except that the illuminated band was wider than usual. The 1st was a clear day, with cirro-stratus moving from slightly north of due west, appearing in the southwest and southern sky in the late afternoon and covering about one tenth of sky at 4:30 p. m. There were also a few of the same clouds near the northwest horizon.—*M. L. Fuller, Local Forecaster.*

Pensacola, Fla.—On November 1st a solar halo was observed at 9:45 a. m. It was partly cloudy from 6 a. m. to 8 a. m., cloudy with upper clouds from 8 a. m. to 11 a. m., partly cloudy from 11 a. m. to 12:30 p. m., then clear past sunset. * * * There were no unusual characteristics in our halo of the 1st.—*Wm. F. Reed, Jr., Local Forecaster.*

Memphis, Tenn.—A solar halo was observed at this station on November 1 at 3:30 p. m. On November 2 there was no halo observed. There is nothing recorded to show that there was anything unusual or remarkable in the appearance of the halo on the 1st.—*S. C. Emery, Local Forecaster.*

Macon, Ga.—None [no halo] was observed here on the 1st, but on the 2nd the phenomenon was seen clearly. It was first noticed in the morning from 10:50 a. m. to about 11:15 a. m. Owing to partial cloudiness which prevailed at that time near the sun, it was only a part of a circle and quite faint. But in the afternoon from 1:40 p. m. to about 3:30 p. m. it was very clear and distinct, a perfect circle most of the time of white light, of about 22° radius. At about 3:30 p. m. the clouds became very dense and it disappeared. Nothing peculiar or unusual was observed in connection with it.—*W. A. Mitchell, Local Forecaster.*

Charleston, S. C.—Bright solar halos of 22° radius were observed on November 1 and 2. That on the 1st occurred from 3 p. m. to 4:30 p. m. and was bright with distinct narrow rim, showing the colors plainly. That on the 2nd lasted from 9:30 a. m. to 5 p. m. and was remarkable for the brilliance of the primary colors, red, green, blue, and the distinct narrow rim. It was much brighter on the segment nearest the zenith and the green was exceptionally vivid. About 4:30 p. m. "sun dogs" were observed north and south of the sun but they were indistinct, being obscured somewhat by alto cumulus clouds. There was a faint lunar halo with no unusual characteristics from 6:40 to 7:50 p. m. of the 2d.—*J. H. Scott, Local Forecaster.*

Houston, Tex.—A solar halo of 22° radius was observed at 1 p. m. November 1, 1913. While plainly visible, nothing unusual was noted. The character of the day was partly cloudy with 0.7 clouds.—*B. Bunnemeyer, Section Director.*

Corpus Christi, Tex.—There was only one solar halo observed at this station. It was first noticed at 12:50 p. m., 90th meridian time, of [November 1]. Forming an uninterrupted circle of no more than 15° radius around the sun, the halo was well defined in colors. No other section of the halo was discovered. A thin layer of alto-stratus clouds covered the sky near the sun at the time. The halo faded away about 2 p. m.—*W. F. Lehman, Observer.*

Augusta, Ga.—On [November 2] the sky was cloudy with cirro-stratus clouds throughout the day and a well-defined solar halo was observed late in the afternoon. There was, however, nothing remarkable or unusual about this halo.—*E. D. Emigh, Local Forecaster.*

Washington, D. C.—At about 3 p. m. of [November 2] at my home in Washington, D. C., I observed a very brilliant solar halo consisting of the usual circle of about 22° radius, a white horizontal band passing through the sun, and brilliant parhelia where this band cut the 22-degree circle on either side of the sun. * * * It was the most perfect solar halo I had ever observed. So far as I can remember, it is the first halo in which I have observed the white horizontal band distinctly.—*Herbert H. Kimball, Professor of Meteorology.*

Columbus, Ohio.—No halo was observed at this station and we find no report of it in the file of the local papers.—*J. Warren Smith, Professor of Meteorology.*

[In reply to a circular letter sent by Prof. Smith to the Weather Bureau coöperative observers in Ohio, reports were received of the appearance of solar or lunar halos, for the most part inconspicuous, on or about the dates in question at a number of places in the eastern half of the State.]

Fort Smith, Ark.—Mr. L. J. Guthrie, Local Forecaster, sends a drawing of a halo seen on October 31, consisting of the circumzenithal arc and the two parhelia of 46°.

THE DIFFERENT FORMS OF HALOS AND THEIR OBSERVATION.[1]

By LOUIS BESSON, Observatoire de Montsouris.

[Translated by Cleveland Abbe, jr., May-June, 1914.]

INTRODUCTION.

Halos are optical meteors produced by the light of the sun or of the moon, in clouds composed of ice crystals. They consist of curves or of luminous foci, either white or tinted with prismatic colors. The remarkable brilliancy they may attain, the extreme variety of their forms, and the somewhat fantastic character of their appearance, make their observance and study most interesting. For these reasons numbers of astronomers and physicists have paid particular attention to them at different times. We owe memorable descriptions of halos to Hevelius. Tycho Brahe observed them carefully at Uraniaborg for 16 years. Among the chief we may mention Huyghens, Mariotte, Fraunhofer, Young, Venturi, Galle, as having studied this class of phenomena and labored more or less successfully to establish a theory of them. The theory was, however, still quite imperfect when Bravais took it up toward the middle of the last century. In a masterly memoir he so far perfected and completed the theory that he seemed to have indeed succeeded in quite satisfactorily explaining all the known forms of halos.

In fact, even today the theory cannot be regarded as other than a more or less probable hypothesis for a very large number of the forms, because existing observations are generally far too few and too inexact to furnish a satisfactory check on the results of computation. This is why the Austrian physicist Pernter, in his recent treatise on meteorological optics, could plausibly reject the Bravais theory relating to three kinds of tangent arcs of the 46°-halo, and substitute another theory which gives them quite different forms.

On the other hand, there is a whole class of extremely rare halos which have been observed but once or twice and remain wholly enigmatical. Not only is their explanation still imperfect, but it will be a long time before we shall have a complete list of their forms. We still have rather frequent reports of combinations and forms that have never been reported during the centuries that have past, and it may be supposed that many unknown forms still await observation.

Halos will, therefore, long offer a fertile field of investigation. Observers should be made aware of this fact in order that a larger number of persons may turn to this field of study. In fact our knowledge of halos can not advance at all rapidly unless numerous persons located at many points on the globe shall observe them. No individual observer, however vigilant throughout his life, can see more than a fraction of the total possible forms of halos. The well-known French meteorologist Renou watched ceaselessly for halos during more than half a century, nevertheless he never saw the oblique arcs of the anthelion, nor the halo of Hevelius, nor the paranthelia of 90°, not to mention many another rarer phenomenon.

From time to time every assiduous observer will find his pains rewarded by his being the first to make some angular measurement or some important discovery; but he will never be able to elucidate more than a portion of the subject by means of his own unaided observations. On the other hand, if there are numerous observers in each country paying intelligent heed to the halos occurring, there can be no doubt that in a few years many uncertainties and gaps will disappear from the theory of these phenomena. Indeed many of their forms, though extremely rare at any given place, probably occur often enough at one place or another upon the earth. * * *

As a matter of fact, the observations on halos published in scientific works are quite inadequate, both as regards quantity and quality. The majority of them are quite devoid of interest since they pertain to phenomena which the observer thought extraordinary, but were really nothing other than more or less brilliant manifestations of known phenomena. Sometimes there are among the described forms, curves whose form is not yet well defined or that appear to be new ones. Unfortunately the descriptions of those portions of the phenomenon whose identity is undoubted almost always reveal such inaccuracies that they greatly weaken our confidence in the observer's other descriptions.

In most cases the observer is a man of science. Often, indeed, he is skilled in the most delicate measurements of physics or of astronomy. If his observation is bad or has not the value that should attach to it, the reason is that he was not familiar with this very special class of phenomena. One observes but poorly that with which one is unacquainted.

Here as in everything else, if one is to do useful work in studying halos it is indispensable that one shall be well acquainted with them and practiced in observing them. Unless one may profit by lessons from an experienced observer for some little time, it is not easy to acquire this practical knowledge. True, various works on meteorology or on general physics present more or less complete lists of halo forms, and a more or less detailed exposition of their theory. None of these sources, however, offer the beginner that practical guidance which would help him to seize in transit, so to speak, these generally fugitive phenomena, and to recognize their often incomplete or indistinct forms. * * *

Having pointed out the insufficiency of halo observations and the advantage of multiplying and improving them, it is now in order that I should facilitate the task of persons disposed to undertake observations and should indicate to those already engaged points to which they should particularly direct their attention.

What are halos?

We shall now pass in review the various known forms of halos, beginning with those of most frequent occurrence and the easiest to perceive.

[1] **Besson, Louis**, Les différentes formes de halos et leur observation. *Extrait du* Bulletin de la Société astronomique de France (mars, avril et mai 1911). Also published separately Paris. [1911?] 22 p., 20 figs. 8°.

In the first place, it is necessary to clearly distinguish between halos and the diffraction coronas that are frequently seen about the moon. The latter may be recognized by the fact that they are in direct contact with the luminary while in the case of a halo the colored ring is separated from the luminary by a relatively dark space whose radius is very rarely less than 22°.

ORDINARY HALO OF 22°.

The halo of 22° is the commonest of all forms (*a*, Fig. 1). At Paris this halo may be seen about the sun on an average of 130 days per annum, to which must be added at least 40 lunar halos of the same class. When the luminary is high in the sky the halo is often perfect,

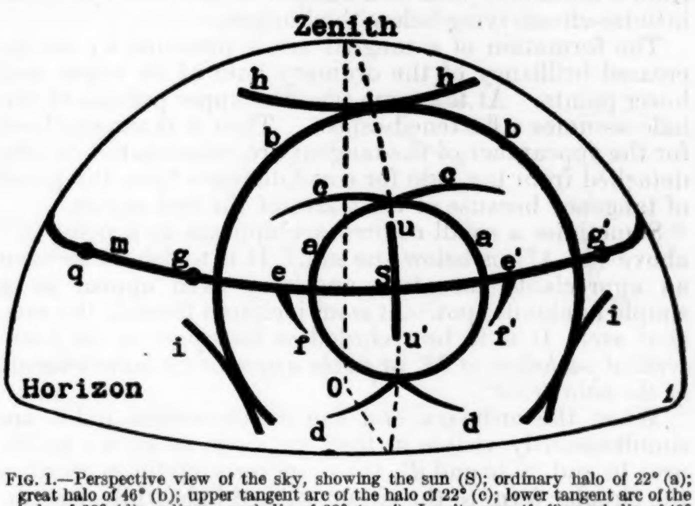

FIG. 1.—Perspective view of the sky, showing the sun (S); ordinary halo of 22° (a); great halo of 46° (b); upper tangent arc of the halo of 22° (c); lower tangent arc of the halo of 22° (d); ordinary parhelia of 22° (e, e'); Lowitz arcs (f, f'); parhelia of 46° (g, g'); circumzenithal arc (h); infralateral tangent arcs of the halo of 46° (i); the parhelic circle (m); a paranthelion of 90° (q); plane of the horizon; the observer (O).

but generally it appears as more or less extensive fragments of varying distinctness.

In spite of its frequency an inexperienced observer may find some difficulty in seeing it for the first time. The most favorable moments are those when the sky is covered with a transparent cirro-stratus veil. The observer, supplied with smoked glasses, places himself so that the sun and its immediate vicinity is hidden by a corner of a roof or some other screening object. Thus shielded from the blinding light, he examines the sky at a distance of 22° from the sun. He is quite likely to perceive there a circle, or rather a luminous ring having the luminary at its center. This ring is colored like the rainbow, but the colors are much less pure. At the inner margin, the only one that is sharply defined, one may distinguish the red, to which succeed outward orange, yellow, sometimes green, and finally a slightly violet-white tint which may extend out several degrees from the inner margin gradually fading away. When the phenomenon is less brilliant one sees scarcely more than a whitish ring with a reddish tinge along its inner margin. This is almost always the case with the lunar halos. Within the ring the sky is relatively dark.

The halo of 22° presents little of interest in optics, but its observation forms the best of preparation for that of the other forms of halos. The observer should practice observing it even when it is only present in its most rudimentary forms. When he has grown familiar with the phenomenon he will find that most of the detached cirri which pass at a favorable distance from the sun, form more or less distinct fragments of this halo.

This halo furnishes material for interesting statistics. First with reference to the annual variation in its frequency. The latter presents a marked maximum in spring in France, England, Scandinavia, Germany, Russia, Siberia, Japan, New York, and over the North Atlantic Ocean. On the other hand at Melbourne the largest number of halos is observed in November and December. It would be desirable to extend this research to other portions of the globe, particularly to the Southern Hemisphere and the Equatorial regions.

Equal interest attaches to the study of the annual variation in the relation of halo frequency to the frequency of cirrus or cirro-stratus, a relation that would measure the aptitude of these clouds to produce the halo. So far this relation has been determined for Paris (2) only,

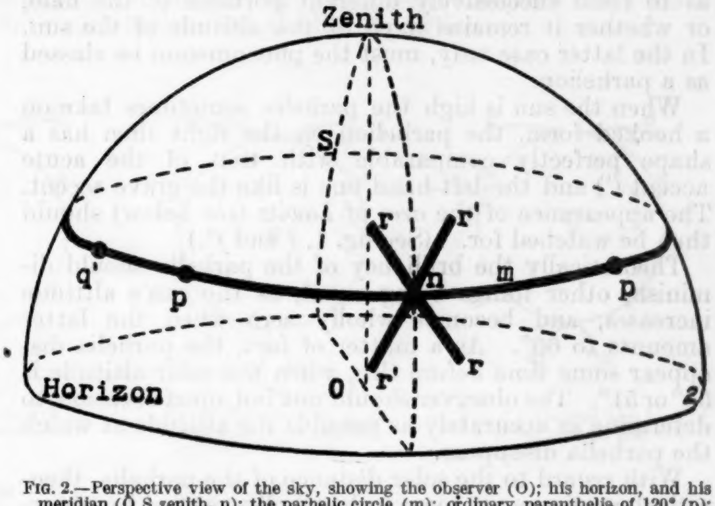

FIG. 2.—Perspective view of the sky, showing the observer (O); his horizon, and his meridian (O S zenith, n); the parhelic circle (m); ordinary paranthelia of 120° (p); the paranthelion of 90° (q'); the oblique arcs of the anthelion (r, r'); and the anthelion (n).

where there is a very pronounced maximum [0.48] in April and a much weaker one [0.32] in October.

Finally it may be pointed out that in certain regions of the globe, the annual number of days with halo seems to show a variation that is either parallel with or inversely as the variation in sun spots. In other regions no relation has been found between the two phenomena (3). It is unfortunate that existing series of good observations on halos are too few and too short to permit us to verify or to determine as precisely as is desirable this interesting result.

ORDINARY PARHELIA OF 22°.

Parhelia are luminous spots appearing to the right and left of the sun and at the same altitude as the latter. (Fig. 1, *e*, *e'*, *g*, *g'*.) When they are produced by the moon they are called *paraselenæ*. Their distance from the luminary, measured along an arc of a great circle, is 22° when on the horizon and increases steadily with the altitude of the source of light. Consequently if the ordinary halo of 22° is also visible the parhelia are located on its circumference when the sun rises or sets, and they stand farther and farther without the halo as the sun approaches the zenith. The halo and the parhelia are distinctly separated, however, only after the sun has reached an altitude of 25° or 30°. (See fig. 1, *e* and *e'*.)

The colors of parhelia are more distinct and purer than are those of halos. They are arranged in the same order as in the latter. The blue is often very pronounced; in fine parhelia it is followed by a violet-tinged white, then

by a pure white forming a horizontal band which may attain a length of 20°. This latter is the *tail of the parhelion* (see fig. 17).

When the parhelia are less brilliant they generally assume the appearance of rounded spots somewhat larger than the sun, whitish in color with a more or less reddish tinge on the side toward the sun and greenish on the opposite side.

When near the horizon the parhelia are frequently elongated vertically. When thus distorted they have some times been compared to fragments of a rainbow. One may then be uncertain whether he has to do with a parhelion or with a limited arc of the halo of 22°. To ascertain this it is necessary to observe whether the luminous arc shifts with the cloud which causes it, so as to form successively different portions of the halo, or whether it remains fixed at the altitude of the sun. In the latter case only, must the phenomenon be classed as a parhelion.

When the sun is high the parhelia sometimes take on a hooked form, the parhelion on the right then has a shape perfectly comparable with that of the acute accent (') and the left-hand one is like the grave accent. The appearance of the *arcs of Lowitz* (see below) should then be watched for. (See fig. 1, *f* and *f'*.)

Theoretically the brilliancy of the parhelia should diminish, other things being equal, as the sun's altitude increases, and becomes wholly zero when the latter amounts to 60°. As a matter of fact, the parhelia disappear some time before this, when the solar altitude is 50° or 51°. The observer should not fail, upon occasion, to determine as accurately as possible the altitude at which the parhelia disappear.

With regard to the solar distance of the parhelia, theoretical requirements seem to be wholly verified by observational determinations at any rate for altitudes of the sun below 40°. Above that altitude we have but few determinations, and they are in poor agreement with the calculated distances. Thus measurements for solar altitudes over 40° would have a very real interest.

At Paris the average annual frequency of parhelia is 35 days. They are generally of shorter duration than the halos. Generally they flare up momentarily, as does a fire into which one throws a quantity of some inflammable substance. They are not always accompanied by the ordinary halo. Frequently but one of them is seen, or they may appear only in succession.

They are less frequently formed by a continuous, homogeneous cirro-stratus veil than by isolated tufts or milky patches of cirrus. Sometimes they momentarily reveal small clouds, invisible before they reached the position of the parhelion and again become invisible as soon as they move away from it. The ice-formed portions of the cumulo-nimbus, known as "false cirrus," are very favorable for the production of parhelia.

Oblique arcs of Lowitz.—The oblique arcs of Lowitz is the name given to luminous arcs which arise at the parhelia and are directed obliquely downward toward the halo of 22° (fig. 1, *f* and *f'*). Barely two observations of this phenomenon are known, and it must be very carefully described if one should observe it. Note carefully the direction of curvature and the exact position of the point of contact with the halo.

Tangent arcs of the halo of 22°.

The halo of 22° may be touched at its highest and its lowest points by luminous curves called, respectively, *the upper tangent arc* and *the lower tangent arc of the halo of 22°* (fig. 1, *c* and *d*).

The form of these tangent arcs varies greatly, according to the altitude of the sun. When the sun has reached 40° or 42°, the two arcs, previously distinct, fuse into a closed curve that is called *the circumscribed halo* or *the elliptic halo* (figs. 9, 10, 18, 20). This curve departs greatly from an ellipse at first, but approaches it more and more closely as the sun's altitude increases. Simultaneously, the interval separating it from the ordinary halo progressively shrinks, and the two curves finally merge into one.

The successive forms assumed by these tangent arcs are presented in figures 3 to 10, which are for solar altitudes ranging from 5° to 55°.

Of course the lower tangent arc is not observable when the sun is lower than 22° unless indeed one is observing from a mountain peak or a balloon whence the eye looks into ice-clouds lying below the horizon.

The formation of a tangent arc is preceded by an increased brilliancy of the ordinary halo at its upper and lower points. At the same time the upper portion of the halo assumes a flattened aspect. Then it is time to look for the appearance of the tangent arc, which is not clearly detached from the halo for some distance from the point of tangency because of the width of the two curves.

Sometimes a small colored arc appears at a point 22° above (fig. 17) or below the sun. It is too short to have an appreciable curvature and may even appear as a simple luminous spot. It is an incipient form of the tangent arc. It is to be recorded as *the upper* or *the lower vertical parhelion of 22°* or as *the upper* or *the lower summit of the halo of 22°*.

When the ordinary and the circumscribed halos are simultaneously visible in their entirety, as shown in figures 10 and 20 (*c* and *d*), the observer sometimes ascribes the circular form to the circumscribed halo while describing the ordinary halo as a vertically elongated ellipse. At other times one believes there are two circles intersecting above and below, as in the sketches forming figures 18 and 20. To be warned of these *illusions* is sufficient to avoid them.

When, in addition to the ordinary halo, or the parhelia, there is yet another phenomenon at or about 22° from the sun, the first thought will be of an ordinary tangent arc. If one compares the observed phenomenon with that one of the forms shown in figures 3 to 10 that corresponds most nearly to the appropriate solar altitude, the agreement will almost always be found to be satisfactory. In spite of the complexity of their changing forms these tangent arcs of the halo of 22° are among the phenomena for which theory is the most certain. Angular measurements, however, may reveal some anomalies due to accessory causes; for example, to oscillations of the ice crystals. It may also happen that other rarer phenomena occur in combination with the usual forms. (See *Extraordinary tangential arcs.*)

In the Temperate Zone the frequency of occurrence of the tangent arcs of the halo of 22° shows a maximum in the Spring and a second less pronounced maximum in the Autumn. At Paris the best opportunity for observing them is at solar altitudes between 30° and 40°, where their average frequency of occurrence is 10 days per annum.

HALO OF 46°.

The halo of 46° is a colored circle having the sun at its center, and resembles the ordinary halo except that it has almost double the radius and is of lesser brilliancy. (Fig. 1, *b*, *b*).

In two-thirds of the cases only the superior portion is visible. Its average frequency at Paris is 8 days per

annum. When the 22° halo attains a lively brilliancy there is approximately one chance in three that the halo of 46° will also appear.

Theoretically, the radius of this great halo is 45° 44′ for the yellow-green color. Measurements carried out at Montsouris Observatory give a slightly different mean radius; but the observed values always show differences among themselves, so that the question arises whether the magnitude measured is truly invariable or whether one is not here dealing with two phenomena of slightly different radii. This is a question demanding further investigation.

CIRCUMZENITHAL ARC.

Sometimes one sees a colored arc above the sun and 46°, or a little more, distant from it. This arc may attain a lively brilliancy and it then presents all the spectrum

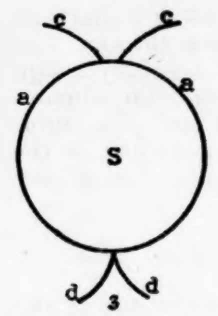

FIG. 3.—Tangent arcs of 22°-halo (a) for solar altitude 5°.

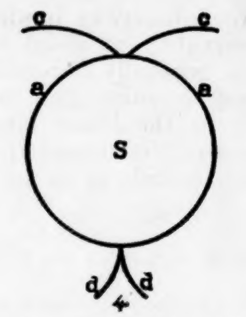

FIG. 4.—Tangent arcs (c, d) of 22°-halo (a) for solar altitude 11°.

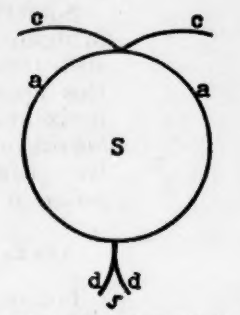

FIG. 5.—Tangent arcs (c, d) of 22°-halo (a) for solar altitude 15°.

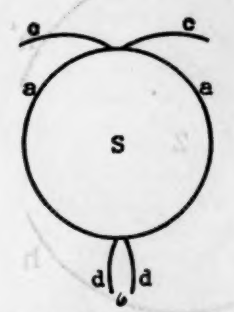

FIG. 6.—Tangent arcs (c, d) of 22°-halo (a) for solar altitude 20°.

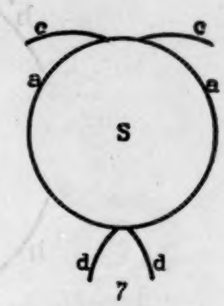

FIG. 7.—Tangent arcs (c, d of 22°-halo (a) for solar altitude 25°.

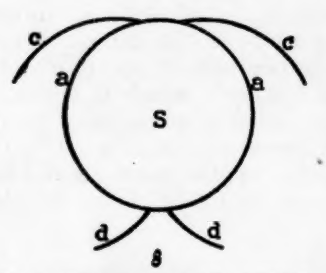

FIG. 8.—Tangent arcs (c, d) of 22°-halo (a) for solar altitude 29°.

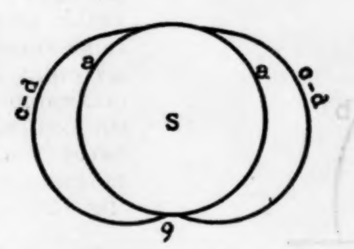

FIG. 9.—Circumscribed halo (c-d) of the 22°-halo (a) for solar altitude 40°.

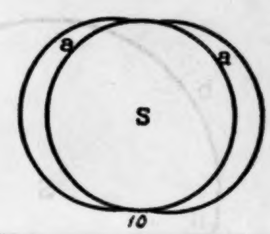

FIG. 10—Circumscribed halo of the 22°-halo (a) for solar altitude 55°.

colors in great purity. This arc is horizontal, that is to say, it forms part of a circumference whose center would be the zenith (fig. 1, *h;* fig. 11, *h*); but one rarely sees more than a fourth or at the most a third of the circle.

Usually the circumzenithal arc does not long remain visible, five minutes on the average. Thus there is little chance of seeing it unless attentively searched for when the circumstances are favorable. It appears only when the sun's altitude is less than 31°, and especially when the sun is near 20°. Out of 10 circumzenithal arcs 6 were observed during solar altitudes between 15° and 25°.

There is an intimate relation between this phenomenon and that of the parhelia. When a cloud that has produced a parhelion, afterwards passes to 46° above the sun the circumzenithal arc rarely fails to appear, of course, provided the solar altitude is favorable. This arc is often formed, as are parhelia, in dense cirrus or in detached tufts of false cirrus. It also frequently appears in the cirriform front or rear margin of cumulo-nimbus. On account of its great altitude above the horizon it is sometimes seen in the icy alto-stratus whose opacity does not permit one to ascertain the position of the sun itself.

According to Bravais's theory the angular solar distance of this arc varies with the altitude of the luminary. When the sun stands at 22° 08′ the solar distance equals the radius of the great halo (45° 44′), and it departs from this value by less than 1° so long as the sun's altitude lies between 17° and 27°; but when the sun is above 27° or below 17° the solar distance of the circumzenithal arc increases rapidly. It amounts to 57° 48′ when the sun is at the horizon or at 32° 12′ and can not form when the sun stands higher than the latter position.

Numerous recent published observations seem to definitely establish this theory, contrary to the opinion of Pernter, who, in his "Meteorologische Optik," rejected the same on *a priori* grounds.

It is, however, desirable to multiply the number of verifications of the theory, especially for solar altitudes exceeding 27°, where we have very few observations of this arc.

It is rare that the halo of 46° and the circumzenithal arc appear simultaneously; when this does occur it is always at solar altitudes approximating 22°. At this time the two curves are tangent to each other, therefore the circumzenithal arc is also called the *upper tangent arc of the 46°-halo.* But it is not impossible that on some day the arc and the halo should appear simultaneously for a solar altitude such that they shall be distinctly separated. Such an observation would be extremely interesting [and was actually made by the author on

December 21, 1910, at Paris when he succeeded in photographing the whole phenomenon (**3a**)].

When one observes an arc at about 46° above the sun, one should at once note the direction of its convexity, whether toward the zenith or toward the sun. Only when the arc is convex toward the sun may it be recorded as the circumzenithal arc.

If the arc is too short or too diffuse to show an appreciable curvature one will record it as the *summit of the halo of 46°* or as the *vertical parhelion of 46°*. When the arc is distinctly concave toward the sun it is generally considered, ipso facto, as belonging to the halo of 46°. There are cases, however, where the arc might be the upper bitangent arc. (See *Upper bitangent arc*, p. 441.)

Kern's arc.—"Kern's arc" is the name given to an arc (fig. 11, *h'*) situated on the same celestial parallel as the circumzenithal arc (fig. 11, *h*), but on the opposite

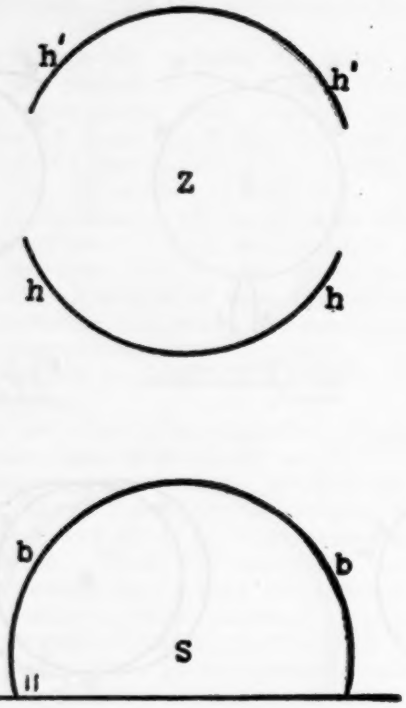

FIG. 11.—Halo of 46° (b), with the circumzenithal arc (h) and Kern's arc (h') about the zenith (Z).

side of the zenith (fig. 11, *Z*). But one observation of this arc is known, viz, that by H. F. A. Kern (**4**) at Lenon, Netherlands, in 1895.

It is here convenient to mention certain observations of abnormal circumzenithal arcs that formed a complete circle about the zenith.

CIRCUMHORIZONTAL ARC.

The circumhorizontal arc is a colored arc which like the circumzenithal arc is parallel to the horizon at a solar distance of 46° or a little more, but it lies below the sun instead of above it. It is also called the *lower tangent arc of the halo of 46°*. Theoretically this arc can be formed only for solar altitudes exceeding 58°. Consequently it may not be observed at Paris except between May 11 and August 1, but at latitudes within 8° of the Equator it is possible to see it on any day toward noon.

So far only three or four observations of this arc are known. It is desired to bring this phenomenon to the attention of observers in low latitudes as they are the most favorably situated for its observation. The atmospheric conditions favoring the formation of the circumhorizontal arc are theoretically the same as those for the circumzenithal arc and the parhelia, but in the actual case the latter can not serve as precursory signs because they are impossible at the great solar altitudes needed to show the circumhorizontal arc.

Very probably the theory for this arc as proposed by Bravais is exactly correct, but so far it has not been verified. The best verification would be to measure the solar distance of the arc under different altitudes of the sun. Theoretically this interval is not exactly equal to the radius of the great halo except for the solar altitude of 68°. If the sun departs in either direction from this altitude then the solar distance of the circumhorizontal arc increases, at first slowly so that it is less than 1° at altitudes between 68° and 63° or 73°, then more and more rapidly as the sun approaches altitudes of 58° or the zenith.

Sometimes one observes a luminous spot or a short arc of insensible curvature at about 46° below the sun. At such times it is generally impossible to definitely assign this appearance to either the great halo, the circumhorizontal arc, or the lower bitangent arc (see *infralateral tangent arcs*), it should then be recorded as the *lower summit of the halo of 46°* or the *lower vertical parhelion of 46°*.

INFRALATERAL TANGENT ARCS OF THE HALO OF 46°.

Colored arcs situated symmetrically either side of and 46° distant from the sun toward which they are convex, are called *infralateral tangent arcs of the halo of 46°* (fig. 1, *i*). They rest upon the horizon as though portions of rainbows. When the halo of 46° is simultaneously visible they are tangent to it (fig. 20, i). The following small table shows the position of the point of tangency according to Bravais's theory, which is also the point of maximum brilliancy. This position may be defined by the central angle α, measured on the circle of 46°, between the lowest point of the circle and the point of tangency of the one or the other of the infralateral arcs (fig. 12).

Positions of points of tangency of infralateral arcs of the halo of 46°.

	°	°	°	°	°	°	°
Solar altitude	0	10	20	30	40	50	60
a	90	86	81	76	70	61	45

Recently Pernter has put forward a new explanation for these arcs, that seems to be inadmissible, while Bravais's theory takes into account the observed characteristics. In order to decide the question with certitude it would be necessary to measure, for various solar altitudes, both the altitude of the point of tangency to the 46°-halo and also as accurately as possible the azimuth of that point or of the brightest point of the arc when the halo is absent. The resulting values should be compared with those given in the above table. Pernter's theory of these infralateral tangent arcs would lead to quite different values for α.

If a theodolite is available and one has sufficient time, he should measure the coordinates of several points on the infralateral arc, thus securing a yet more complete verification. At present we have but one angular measurement (**5**) relating to these arcs and that measurement conforms to Bravais's theory.

The best chances for observing the infralateral tangent arcs of the halo of 46° occur when there is a brilliant display of the tangent arcs of the halo of 22°. The two phenomena are closely related, but the former is much rarer than the latter.

Lower bitangent arc.—Theory says that when the sun has reached an altitude of 60° the two infralateral arcs unite to form a single curve which Bravais calls the *lower bitangent arc.* As the sun ascends above 60° this curve

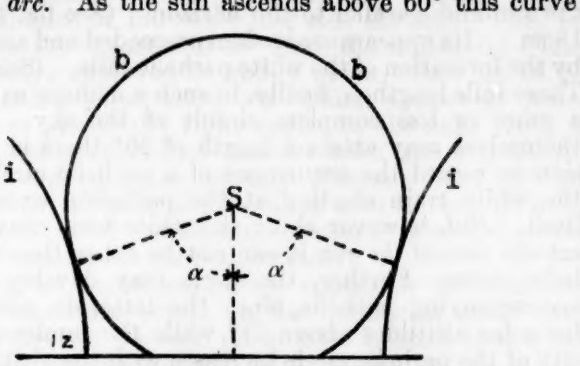

FIG. 12.—Halo of 46° (b) and the infralateral tangent arcs (i) of that halo; showing the angular position (α) of the point of tangency on "b."

steadily approaches the halo of 46° and when the altitude of 68° has been attained it becomes sensibly identical with the lower third of the halo. As the sun mounts yet higher this curve separates exteriorly from the great halo as an arc of a concentric circle tangent to the circumhorizontal arc.

This lower bitangent arc has never been observed. It could be observed only from points below latitude 53° and the best chances for observing and verifying it would be in the equatorial regions; an interesting theoretical prediction.

UPPER BITANGENT ARC.

His theory led Bravais further to foresee the possibility of another luminous curve, also doubly tangent to the halo of 46° but on its upper side. This curve is the *upper*

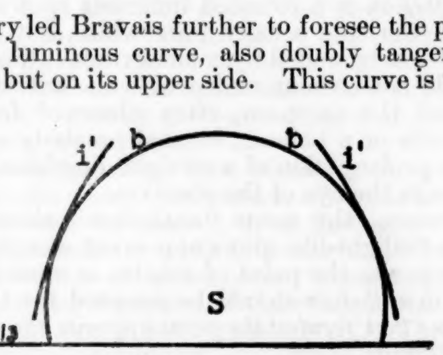

FIG. 13.—Supralateral tangent arcs (i') of the 46°-halo (b).

bitangent arc. It is very difficult to distinguish this from the halo of 46°, from which it is but slightly separated. It had not been reported by any observer until September 26, 1910, but on that date was manifested at Paris in so characteristic a manner (6) that its actual existence seems to be incontestibly established.

When the sun is low the summit of this arc is normally too faintly luminous to be perceptible; it then consists of two symmetrical arcs laterally tangent to the halo of 46°. (See fig. 13.) Bravais calls them the *supralateral tangent arcs.* If the sun's altitude increases the two points of tangency approach the summit of the great halo and the union of the two arcs becomes increasingly evident. When the sun reaches an altitude of 22° the point of tangency is exactly in the sun's vertical and the arc becomes sensibly identical with the upper portion of the halo. When the sun ascends from 22° to 32°, the latter altitude being the upper limit for the phenomenon to form, the arc gradually separates from the halo while preserving the form of an arc concentric with it.

Theoretically, if the generating ice crystals continue in perfect equilibrium the bitangent arc ought to be tangent at its culminant point to the circumzenithal arc supposed to be simultaneously visible. In reality, however, the ice crystals are always in oscillation which results in displacing the two curves so that they no longer remain exactly tangent but may mutually intersect. Figures 14, 15, and 16 show such forms observed September 26, 1910.

FIGS. 14, 15, 16.—Forms of the upper bitangent arc (i'₁) of the 46°-halo, in combinations with the circumzenithal arc (h).

Figure 14 shows much analogy with an old observation by Beckerstedt in 1763 (see fig. 17) and cited by Bravais in support of his theory. The halo of 46° would not be able to produce such forms as these figures show; they are characteristic of the upper bitangent arc but seem to be of very rare occurrence.

Sometimes when the sun is low, one may see *simultaneously with the tangent arc of the 22° halo,* an arc having approximately the form of a fragment of the 46°-circle. The colors of this arc are purer than those of the halo and

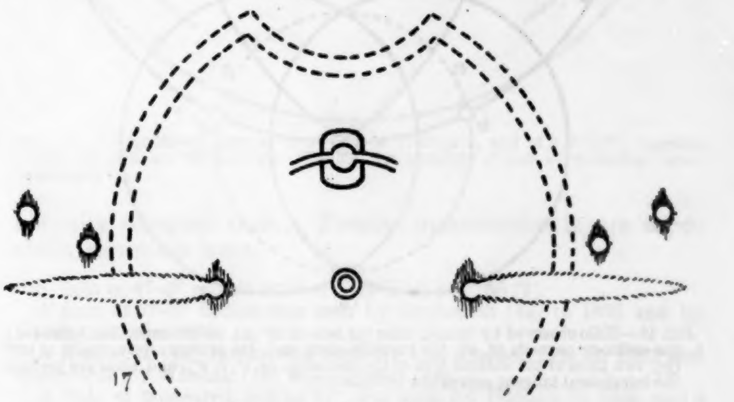

FIG. 17.—Halo observed by Beckerstedt in 1763.

the maximum brilliancy is not at the summit but at a certain distance to the right or the left. Probably this is a supralateral arc occurring either alone or superposed upon the halo of 46°. One should determine whether the point of maximum brilliancy is at the theoretical point of tangency for the two curves. It would be still better to measure, if possible, the solar distance of the inferior extremity of the luminous curve. If the phenomenon is indeed a supralateral arc and of sufficient length, the solar distance ought to prove noticeably more than 46°.

On the other hand, when the sun is higher than 22°, and *always simultaneously with the tangent arcs of 22°,* it sometimes happens that at about 46° above the luminary one may see an arc having the pure colors of the circum-

zenithal arc but with descending branches. Probably this also is the upper bitangent arc. To prove it with certainty one should, as in the preceding case, measure the solar distance of the arc which in this case is readily done by simply measuring its altitude in the sun's vertical. If the sun is at least 28° high even a rather rough determination ought to show a solar distance clearly greater than 46°.

PARHELIA OF 46°.

There have been a number of observations of colored parhelia analogous to the ordinary parhelia of 22° but

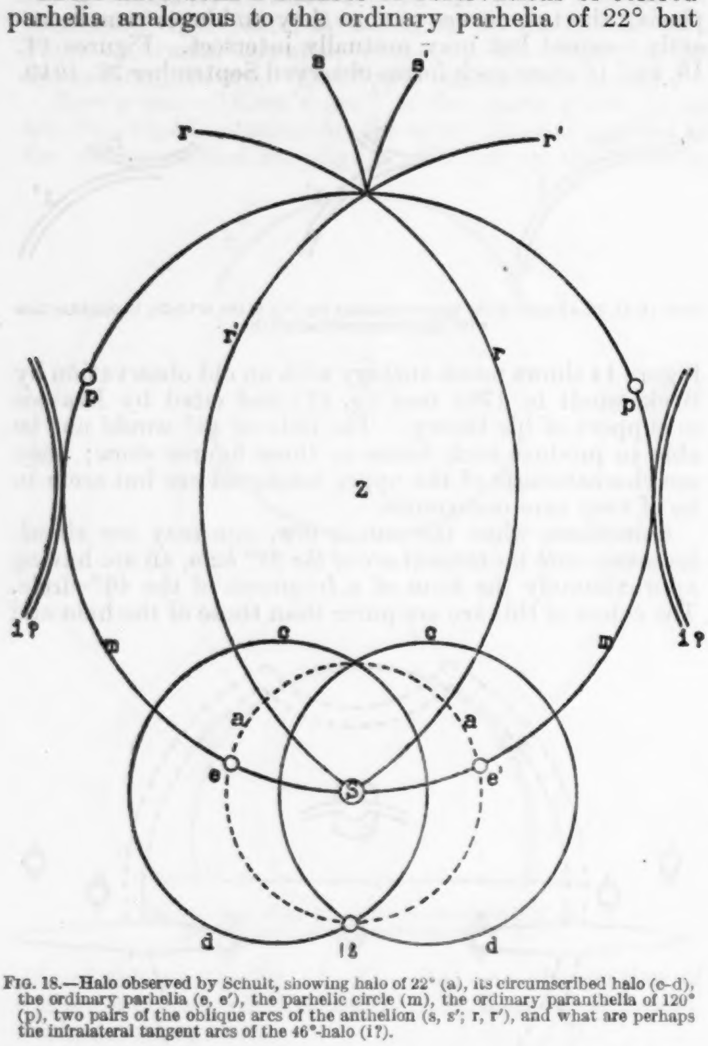

FIG. 18.—Halo observed by Schult, showing halo of 22° (a), its circumscribed halo (c-d), the ordinary parhelia (e, e′), the parhelic circle (m), the ordinary paranthelia of 120° (p), two pairs of the oblique arcs of the anthelion (s, s′; r, r′), and what are perhaps the infralateral tangent arcs of the 46°-halo (i?).

located on the halo of 46° or, in its absence, at a solar distance approximately equal to the radius of that halo and at the same altitude as the luminary. (Fig. 1, *g g′*.) This is one of the rarest of phenomena. Two explanations of it have been offered leading to quite different consequent solar distances and limiting altitudes at which it can take place. The limiting solar altitude, *H*, in the one case (*a*) is 32° 12′, and in the other case (*b*) 60° 45′. As for the solar distance, *D*, of the parhelion measured on an arc of a great circle, it varies with the altitude, *H*, of the luminary according to the one hypothesis or the other as shown by the following table:

Solar distances of the parhelion of 46°.

H.	0°		10°		20°		30°		40°		50°	
	°	′	°	′	°	′	°	′	°	′	°	′
D_a.....	45	44	46	00	50	38	61	52	.....	.....	.....	.....
D_b.....	43	40	43	54	46	00	49	12	53	56	60	24

So far we have but one measurement (7) of the solar distance of the parhelion of 46°, which was made at the solar altitude of 3°. This measurement is much more favorable to hypothesis (*a*) than to hypothesis (*b*).

PARHELIC CIRCLE.

The parhelic circle is a white circle passing through the sun and parallel to the horizon. (See fig. 1, *m*; fig. 18, *m*.) Its appearance is often preceded and announced by the formation of the white parhelic tails. (See fig. 17.) These tails lengthen, finally, in such a manner as to make a more or less complete circuit of the sky. As they themselves may attain a length of 20° there is no occasion to record the occurrence of a parhelic circle unless the white train starting at the parhelion exceeds this limit. *But*, however short the white train may be *if it extends toward the sun* it can not be other than the parhelic circle. Further, the circle may develop without accompanying parhelia, since the latter do not appear for solar altitudes above 51°, while the luminous intensity of the parhelic circle increases with the altitude.

The white band that forms the parhelic circle sometimes has a reddish border that should be recorded if it is observed.

The parhelic circle often develops very suddenly, and its circumference may show knots of white light, though they are sometimes of very brief duration. They must be carefully watched for, as these diffuse images of the sun sometimes present the anthelion and the paranthelia. (See figs. 2 and 18.) When the moon is the luminary, these phenomena are called the paraselenic circle, [paraselenæ], antiselene, and parantiselenæ, respectively.

Anthelion and the oblique arcs of the anthelion.

The *anthelion* is a rounded luminous spot situated at 180° from the sun, usually pure white, but it may be iridescent or surrounded by colored rings. (See fig. 2, *n*.)

It should not be confounded with the antisolar corona or glory of the aeronaut, often observed from mountain summits or a balloon, located precisely opposite to and in the prolongation of a straight line from the luminary through the eye of the observer.

Furthermore, the name "anthelion" should not be applied to twilight-like glows appearing at a point on the horizon opposite the point of sunrise or sunset.

The term *anthelion* should be reserved for those *luminous images that form at the point opposite the sun and at the same altitude.*

Oblique arcs of the anthelion.—The anthelion may appear when the parhelic circle is absent. Sometimes the anthelion is traversed by ascending white intersecting arcs called *the oblique arcs of the anthelion.* (See fig. 2, *r, r′*.) This is a very rare phenomenon and its theory is still quite uncertain. These arcs may apparently be classified according to their inclination, into two different kinds both of which may occur simultaneously, as in Schult's observation, reproduced in figure 18. Sometimes these arcs are prolonged until they recross in the sun itself, as occurred on that same occasion. (See fig. 18, *r* and *r′*.)

When these arcs are observed one should measure, or estimate if there is no instrument available, their angular inclination. Their course on the celestial sphere should also be determined as exactly as possible, as should be their second point of intersection if they have one. Observe their width, whether it is uniform or increases with the distance from the anthelion.

The oblique arcs may appear without a simultaneous anthelion strictly so-called, i. e., a rounded image of the sun at their point of intersection. They have sometimes shown iridescence also.

Paranthelia.

The so-called ordinary paranthelia of 120° appear at an azimuth of 120° on either side the sun. They are mutually 120° apart and 60° from the anthelion. They have always appeared as wholly white. (See fig. 18, *p.*)

Sometimes paranthelia, also white, appear at points located at practically right angles to the sun. (Fig. 2, *q'*.) Is their azimuthal distance from the sun exactly 90°? Is this distance slightly different from 90° but constant for all solar altitudes, or does it vary with the latter? Lack of precise measurements does not permit of exact answers to these questions.

Still other paranthelia may appear at different and equally uncertain points on the horizontal small circle passing through the sun. A notable location is at about 40° from the anthelion.

LIGHT PILLARS AND CROSSES.

A light pillar is a train of light extending vertically above the sun or moon, and it may also be prolonged beneath the luminary. In width these pillars differ but little from the diameter of the luminary; their length is very variable, sometimes being less than a degree and again amounting to 30 or 40 degrees. (See fig. 1, *u, u'*.)

The *light pillar* must not be confused with the luminous rays that sometimes seem to escape from the edges of the lower clouds when these hide the sun. Such rays diverge from the sun in all directions and are vertical but by accident, while the light pillar is and remains always vertical. It is also not to be confused with the rosy twilight bands that radiate from the setting sun and sometimes traverse the whole sky, apparently reconverging at the opposite horizon. Almost always there are several such bands at the same time, and they also are vertical only by accident.

Bravais distinguishes *light pillars of the first class* or those that rise above the horizon after sunset; and *light pillars of the second class* or those that appear above or beneath the luminary while it is above the horizon.

Crosses.—Solar or lunar crosses consist of two trains of light, the one vertical and the other horizontal, intersecting at the sun or moon respectively. The horizontal arm is usually interpreted as a fragment of the parhelic [or paraselenic] circle. (Compare fig. 1, *u, u'*, and *m*.)

Pseudhelia and mock suns.

The *pseudhelion* is a white image of the sun symmetrically located with reference to the luminary and the plane of the horizon. The phenomenon is visible only to an observer in a balloon or on a mountain. Bottlinger (**8**) has seen it surrounded by a small elliptical ring.

Other *mock suns*, to which the term should be restricted, appear toward sunset or sunrise in contact with the true sun and located in its vertical. This phenomenon is usually accompanied by a light pillar and very probably is genetically related to the halos, but it has not yet been satisfactorily explained.

HALOS OF ABNORMAL RADIUS.

On various occasions there have been observed circular solar or lunar halos analogous to those of 22° and 46° but having a different radius. In the majority of cases there has been no direct measurement of the radius of the abnormal halo; it has been estimated in terms of the ordinary halo that is almost always simultaneously visible. Under such circumstances the error may easily amount to 2°; besides, it is often impossible to decide in the case of two observations of this kind, whether the observations refer to the same halo or to two halos of

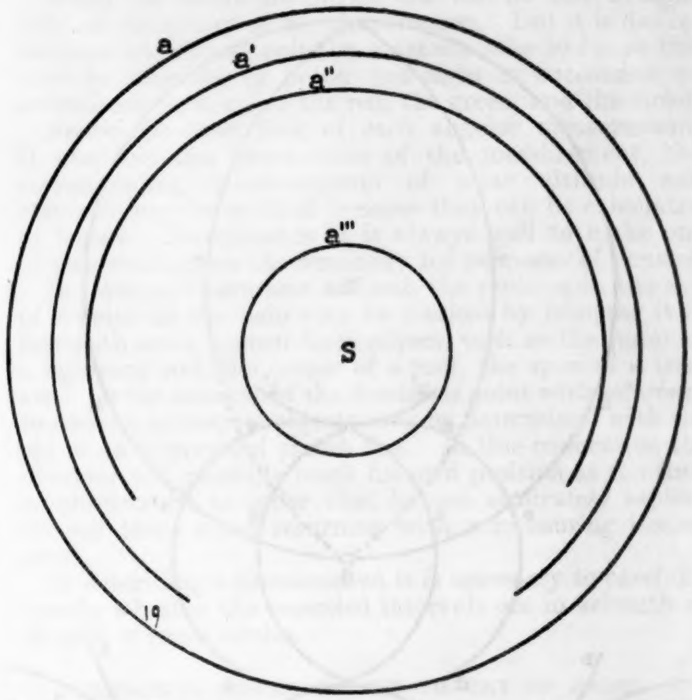

FIG. 19.—Extraordinary halos of 19.5° (a'), of 17.5° (a''), and of 7.5° (a'''), together with the ordinary 22°-halo (a). Hissink has observed a' and a'' occurring simultaneously.

actually unequal radii. Precise measurements are especially desirable here.

A halo of 4°–6° radius was seen by Hall in 1796 (9).

A halo of 7°–8° radius was seen by Arctowski (10) in 1898 and by Hissink (11) in 1899.

A halo of 9°–10° radius was seen by Van Buijsen (12) in 1892 and afterwards by Hissink (13) and Russell (14).

A halo of measured radius 14° was seen by Heiden in 1839 and a halo of measured radius 16° by the same at the same time.

A halo of about 17° was seen by Besson and Dutheil (15) in 1900.

A halo of measured radius 17° 55′ was seen by Hissink (16) in 1899 and 1905, and afterwards by Krčmar (17).

A halo of measured radius 19° 25′ was seen by Burney in 1831, and afterwards on three occasions by Hissink (18).

The two halos last mentioned were certainly different circles, as they have been observed simultaneously by Hissink (see fig. 19).

A halo of 26°–29° was seen by Scheiner in 1629, and afterwards by Greshow and by Whiston.

A halo of 34°–38° was seen by Feuillée, by Parry, and by the members of the Charcot expedition in 1904 (19).

A halo of about 90° was seen by Hevelius in 1661, afterwards by Erman, Sabine, and others. In contrast to the preceding halos which are colored like the 22° halo, the halo of Hevelius has always appeared as a white circle. The exact determination of its radius would be of special interest.

We would add that sometimes confusion has arisen by applying the name "white rainbow" to a phenomenon

almost identical in magnitude and appearance but quite different in its nature from the degenerating form of the true rainbow which forms the true white rainbow. This *false white rainbow* is still of problematic character, but it should be due to ice crystals, as are the halos. It would seem to be a halo of about 140° radius.

EXTRAORDINARY UPPER AND LOWER TANGENT ARCS OF THE 22°-HALO.

In exceptional cases there may be arcs other than the ordinary tangent arcs, touching the halo of 22° either at

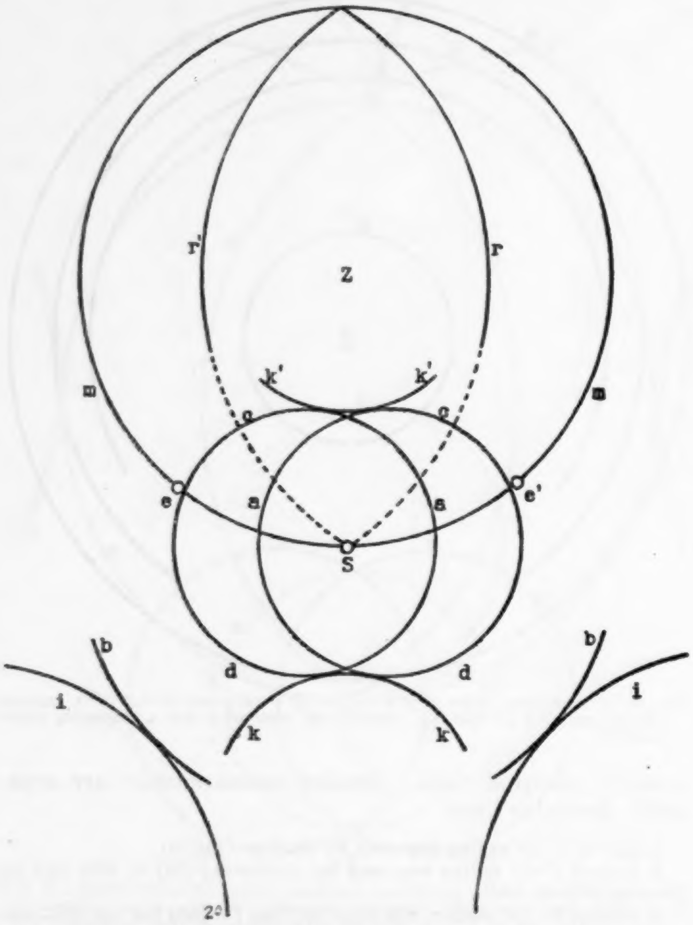

FIG. 20.—Halo observed by Rear Admiral A. von Kalmar, at Pola, on March 26, 1896, embracing: Halo of 22° (a), circumscribed halo of 22° (c–d), ordinary parhelia (e, e'), extraordinary tangent arcs of the halo of 22° (k, k'), infralateral tangent arcs (i, i') accompanying fragments of the 46°-halo (b, b), the parhelic circle (m), the oblique arcs of the anthelion (r, r'). S, the sun; Z, the zenith.

its summit or its base. Such are the arcs shown at k' and k of figure 20, which were observed by Vice Admiral Kalmar (**20**). Two kinds of such arcs have been observed, viz:

1. *Arcs parallel to the horizon.*—The arcs parallel to the horizon are, according to Bravais, "secondary" parhelic circles engendered by the very brilliant vertical parhelion situated at the point of tangency with the halo, and which plays the part of the luminous source.

2. *Arcs not parallel to the horizon.*—Bravais has proposed a theory of the arcs not parallel to the horizon that does not accord well with the observations. Exact determinations of their curvature are needed.

Infralateral and supralateral arcs of the 22°-halo.

Enigmatical arcs that touch the upper or the lower side of the 22° halo are called the supralateral or the infralateral arcs, respectively, of the 22°-halo. The dextral supralateral arc was first observed by Az. de Ruijter (**21**) in 1898. Manois (**22**) observed the two infralateral arcs in 1901. In 1904 the dextral supralateral (j') and infralateral (j) arcs as shown in figure 21 were observed in Holland (**23**).

In the existing state of our knowledge of ice crystals it is very difficult to explain these arcs.

OBLIQUE PARHELIC CURVES.

There have been several observations of bands of white light passing through the luminary in the manner

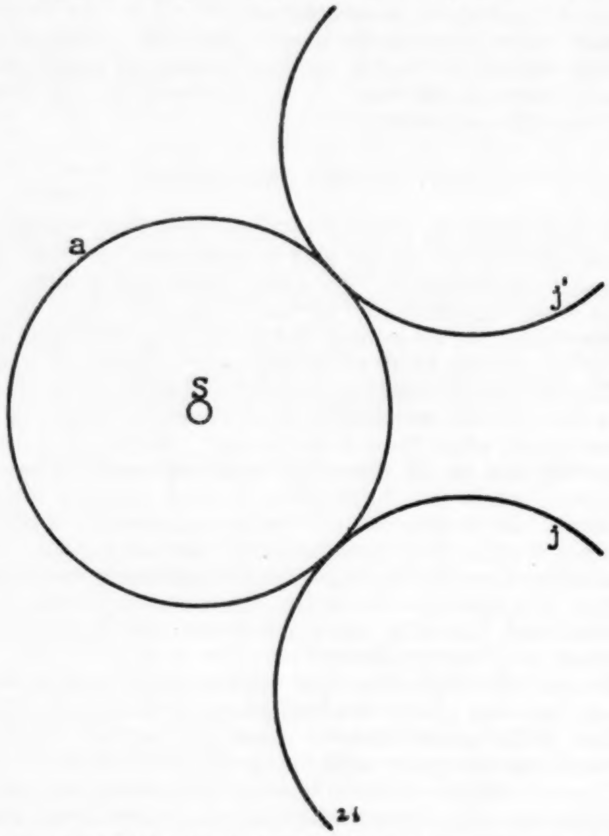

FIG. 21.—Halo of 22° (a) with the dextral infralateral (j) and supralateral (j') arcs S, the sun.

of the parhelic circle, but departing noticeably from a horizontal position. The theory of these *oblique parhelic curves* is very uncertain. In 1904 Mellema (**24**) saw two parhelia on a curve of this class.

EXTRAORDINARY CIRCUMZENITHAL ARCS.

Horizontal or approximately horizontal arcs appearing above or below the sun, but differing from the upper and lower tangent arcs of the 22°- and 46°-halos, are called *extraordinary circumzenithal arcs*. They have been observed particularly at about 18°, 26°, 33°, and 54° above the luminary.

A general theory of these arcs has been outlined by Bravais, who finds that their horizontality is never other

than an approximate one. He does not explain the horizontal closed circles that have been observed on numerous occasions.

SECONDARY HALO PHENOMENA.

It is a recognized fact that if a parhelion or any other luminous focus is sufficiently brilliant it may "secondarily" engender halo phenomena such as parhelia, a 22°-halo, a parhelic circle. As we have seen (p. 444) this seems to be the origin of certain extraordinary tangent arcs. Pernter (**25**) observed a circle of 22° and two parhelia that were evidently secondary phenomena about an ordinary lower tangent arc of the 22°-halo which appeared as a luminous oval of the form shown in figure 4.

SINGULAR PHENOMENA.

In closing I would direct attention to some phenomena that have been seen but once, and in every way deserve the designation *singular:*

1. *A small elliptical helio-centric halo;* its major axis placed vertically and 21° in length, its minor axis being 15° long. It was observed and measured by Hissink (**26**) in 1901. A somewhat analogous phenomenon is shown on a sketch by Wagner dated 1733.
2. *An elliptical seleno-centric lunar halo* tangent to the 22°-halo at either end of the horizontal major axis, and having a minor axis of 20° or 22°. It was observed in 1904 by the Charcot expedition (**27**).
3. *Two white arcs seen* in 1898 *by Arctowski* (**28**) simultaneously with a (false?) white rainbow, placed at 90° on either side of and at the same altitude as the rainbow.
4. *An arc obliquely intersecting the upper left-hand part of the 22°-halo.* This arc was observed by Barrett (**29**) in 1905.
5. *Colored parhelia* seen by Aveline in 1798, located on the parhelic circle *about 44° from the sun* and with their more brilliant portions turned *away from* the luminary.

PRACTICAL DIRECTIONS FOR OBSERVING HALOS.

Record the successive phases of the phenomenon, stating the exact time of occurrence of each phase together with the corresponding variations in the appearance of the sky.

State the time used, whether mean local or the mean time of some definite meridian.

When the visible curves or luminous spots are recognized *designate them by their proper names;* record their peculiarities and endeavor to carry out the checks or measurements which are given above as desirable.

If an unknown phenomenon appears, first examine its form, its position with reference to the sun and to the other luminous phenomena, its colors and their arrangement, and record the exact time of the observation.

If paper and pencil are at hand, at once *make a sketch of the phenomenon.* Later carry out angular measurements if possible. The use of photography is always to be recommended, but should never be substituted for the observations according to the directions just given.

Never combine in one drawing phenomena observed at different times.

The method of projection exemplified in figures 18 and 20 is a convenient one for representing appearance of a phenomenon that occupies a large portion of the heavens, but the form and proportions of the curves are necessarily altered. The interesting portions of the phenomenon should be drawn separately and true to nature.

Angular measurements.—Angular measurements may refer to three elements—altitude above the horizon, the azimuth, and the mutual distance of two phenomena or of the luminary and the phenomenon.

A theodolite gives both altitude and azimuth at one setting.

Altitude alone may be determined by a clinometer or by a mercury level conveniently graduated (**30**).

Azimuth may be determined by the aid of a compass and a plumb line, provided the altitude of the point measured does not exceed 30°.

The radius of a halo or the solar distance of a notable luminous point may be readily measured with sufficient exactness by the aid of a sextant or reflecting circle.

The lenses of the telescope on the sextant or the theodolite should be removed for this work, as the phenomena can not be perceived through them.

When the colors are diffuse one will be able to sight only on the center of the phenomenon. But it is desirable that one should *point on a definite color* so far as this may be possible, or better yet sight in succession on several colors, e. g., on the red, the green, and the violet.

Record the exact time of each angular measurement. If one has this exact time of the measurement, the corresponding measurements of solar altitude and azimuth may be omitted because they can be calculated at leisure. Nevertheless it is always well to make one or two settings on the luminary for purposes of control.

Is there *no instrument at hand,* the position in the sky of a point on the halo may be marked by bringing it in line with some known fixed object, such as the point of a lightning rod, the corner of a roof, the apex of a tree, etc. Or the azimuth of the luminous point with reference to distant terrestrial objects may be determined with the aid of an improvised plumb line. In this connection the observer will carefully mark his own position at the time of observation in order that he can accurately replace himself there when returning with a measuring instrument.

In describing a phenomenon it is necessary to carefully specify whether the recorded intervals are in azimuth or on arcs of great circles.

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Pernter, J.-M. & Exner, F. M. Meteorologische Optik. Wien, Leipzig. 1902–1910. 799 p.

Besson, Louis. Sur la théorie des halos. Annales de l'Observatoire de Montsouris, 1908 and 1909.

REFERENCES AND NOTES.

(2) **Besson, L.** La théorie des halos. Annales de l'Observatoire de Montsouris, 1908, p. 358.

On page 359 of this work Besson gives the following numerical results of some of his observations at Paris:

Monthly ratios of the number of cases of 22°-halos to the number of cases of cirrus clouds at Paris.

January	0.22	June	0.39	November	0.25
February	0.30	July	0.29	December	0.27
March	0.36	August	0.25		
April	0.48	September	0.30	Year	0.32
May	0.43	October	0.32		

(3) Annuaire de la Société météorologique de France, 1906, p. 115.

(3a) **Besson, L.** Un arc tangent qui n'est pas tangent. La Nature, Paris, 1911, **39**, 1[er] sem., p. 247–248, illus.

(4) Koninklijk nederlandsch meteorologisch Instituut. Onweders, optische verschijn., enz., in Nederland, 1895, p. 66.

See also Maanblad voor Natuurwetenschappen, 1896, No. 5.

(5) Annales de l'Observatoire de Montsouris, 1909, p. 183.

(6) Comptes rendus, **151**: 693.
(7) Annuaire de la Société météorologique de France, novembre, 1900, p. 7.
(8) Meteorologische Zeitschrift, 1910, **27**. Jhrg., p. 74.
(9) This and all other observations for which no bibliographic references are given, are from Bravais, Mémoire sur les halos.
(10) Résultats du voyage du S. Y. *Belgica*: Arctowski, Phénomènes optiques, p. 32.
(11) Onweders, optische verschijn., enz., 1899, p. 57.
(12) Onweders, enz., 1892, p. 60.
(13) Onweders, enz., 1899, p. 62.
(14) Symons's meteorological magazine, March, 1907.
(15) Annuaire de la Société météorologique de France, novembre 9, 1900, p. 7.
(16) Onweders, enz., 1899, p. 57; and ditto, 1905, p. 81.
(17) Meteorologische Zeitschrift, 1907, **24**. Jhrg., p. 87.
(18) Onweders, enz., 1899, pp. 57, 62; and ditto, 1905, p. 81.
(19) Not published.
(20) Meteorologische Zeitschrift, 1896, **13**. Jhrg., p. 183.
(21) Onweders, enz., 1898, p. 50.
(22) Annales de l'Observatoire de Montsouris, 1901, p. 304.
(23) Onweders, enz., 1904, p. 71.
(24) Onweders, enz., 1904, p. 70.
(25) Meteorologische Zeitschrift, 1888, **5**. Jhrg., p. 201.
(26) Onweders, enz., 1901, p. 65.
(27) Unpublished.
(28) Résultats du voyage du S. Y. *Belgica*: Arctowski, Phénomènes optiques, p. 40.
(29) Greenwich magnetic and meteorological observations, 1905.
(30) This instrument is described in Comptes Rendus, Paris, 1905, **140**: 960.

HALOS AND THEIR RELATION TO THE WEATHER.

By ANDREW H. PALMER, Assistant Observer.

[Dated Weather Bureau, San Francisco, Cal., July 15, 1914.]

When rays of light from the sun or the moon pass through a cloud sheet, various subjective phenomena are caused by the moisture particles which make up the cloud mass. When the sun is observed through haze or attenuated fog it appears as a disk with sharply defined edges. When a moderately dense cloud sheet occurs at a low or intermediate level, the sun's disk, when visible, is irregularly defined, is sometimes too bright to be observed directly with the naked eye, and is frequently surrounded by concentric rings of light called coronas. These rings, which vary in number from time to time, are ordinarily 1° to 5° in radius, and show the various colors of the spectrum, always with the red on the *outside*. They are produced through diffraction and interference of the light rays by the water spherules and ice crystals encountered. Because of the brightness of the sun many solar coronas pass unobserved, as they usually may be seen only by reflected light. Incomplete coronal arcs are often seen in the thin margins of broken clouds like strato-cumulus and alto-cumulus. With the highest cloud sheet, the cirro-stratus, refraction and reflection of the rays by the ice crystals produce rings in which the colors, when visible, are always arranged with the red on the *inside*. These are halos proper or greater halos, and may be defined as somewhat complicated arrangements of arcs and circles of light surrounding the sun or the moon, accompanied by others tangent to or intersecting them, with spots of special brightness called parhelia appearing at the points of tangency and intersection. Parhelia are most often observed about sunrise or sunset, frequently when the intersecting arcs are themselves invisible, except at the points where the two causes combine to reflect a double portion of the sun's rays. In the order of their frequency, halos average about 22°, 46°, or 90° in radius, but on rare occasions various other sizes have been observed. In the following discussion halos proper are alone considered.

There is a very intimate relation between halos and cirro-stratus clouds, a halo usually being formed whenever this kind of cloud is penetrated by the rays of the sun or the moon. Based upon the observations made at Blue Hill Observatory during 1896-97, the mean height of cirro-stratus clouds is 10,099 meters during April to September, inclusive, and is 8,893 meters during October to March, inclusive (1). The mean for the year is 9,496 meters, an average higher than that of any other form of cloud. The maximum height at which they have been observed is 13,601 meters, while an instance of cirro-stratus cloud at 4,036 meters is also on record. However, it is sufficient to say that they are high clouds, so high in

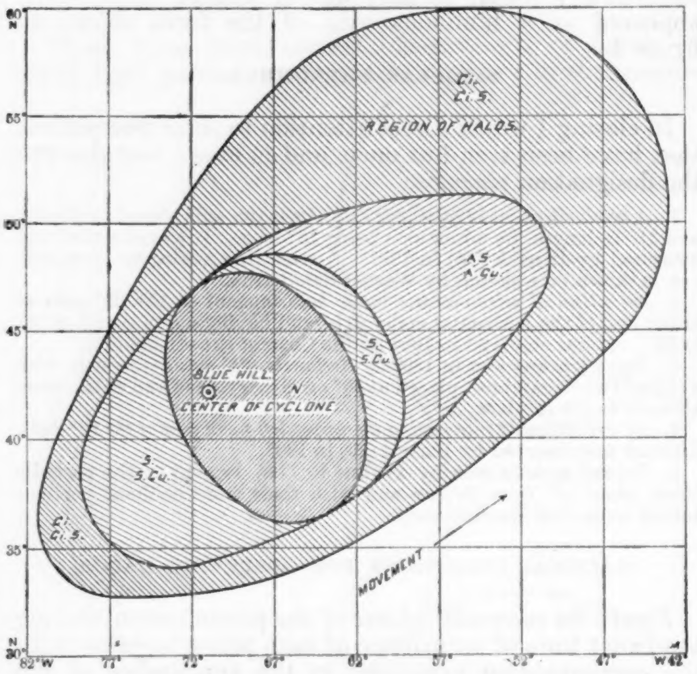

FIG. 1.—Cloud regions and cloud classes about a typical Northern Hemisphere cyclone central over Blue Hill Observatory. (International cloud notation.)

fact that the water particles making up the cloud are known always to be in the form of hexagonal prisms of ice. Though it is unnecessary to consider the physics of halo formation here, it should be stated that the form and the arrangement of these ice spicules or needles are important considerations in the refraction and the reflection of the light rays (2). The size of the halo, whether it be approximately at 22°, 46°, 90°, or one of the rarer types, is determined by the amount of reflection and refraction suffered by the rays, and is therefore closely dependent upon the density, the thickness, and the height of the cirro-stratus sheet. While most halos are approximately circular, a few are elliptical, the latter form being explained sometimes by inequalities in distance between the observer and the moisture particles, and sometimes by the distortion resulting from heterogeneous conditions of temperature, and hence of density in the lower atmosphere. The light of some arcs is polarized, while that of others is not (3). From a study of halos observed in Russia, Dr. Ernst Leyst concluded that there was no relation between halos and sunspots (4).

At Blue Hill Observatory, which is located upon the summit of a high hill 10 miles south of Boston, Mass., record is kept of the occurrence of halos among the other miscellaneous phenomena. The kind of halo, whether solar or lunar, and the duration of its existence, is re-

corded. Though no record as to size is kept, the 22°-halo is by far the most common, and the 46°-halo the next most common. As pointed out by M. E. T. Gheury (5), who made a study of halos and coronas observed in England, one does not realize how common halos are until he keeps a systematic record of their occurrence. Table 1 shows the monthly occurrence of halos, both solar and lunar, as recorded at Blue Hill Observatory during the 20 years, 1891 to 1910, inclusive. Doubtless practically all of the solar halos which have been visible there during that time have been recorded, but many lunar halos have probably been unnoticed, since no observer is on duty between midnight and 7 a. m. It is apparent from the table that solar halos are most frequent in the spring, the mean number for March being 5.9, and are least common in the autumn, October and November each having a mean of 2.3. Lunar halos are most frequent in winter, the mean for January being 2.7 and are least frequent in summer, the mean for June, August, and September being but 0.6.

TABLE 1.—*The numbers of halos observed at Blue Hill Observatory, Great Blue Hill, Mass., 1891–1910, inclusive.*

SOLAR HALOS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1891....	4	5	5	3	7	5	7	0	1	0	3	2	42
1892....	5	2	6	6	3	3	3	2	3	1	1	4	39
1893....	1	3	2	2	3	4	5	3	2	4	4	3	36
1894....	5	6	9	5	4	3	2	1	2	2	4	4	47
1895....	10	5	10	4	5	4	4	7	0	4	1	8	62
1896....	4	3	6	3	4	2	0	0	5	2	3	5	37
1897....	4	5	2	5	2	5	2	0	2	2	1	4	34
1898....	7	4	9	7	4	1	0	2	2	1	0	7	44
1899....	3	5	3	0	5	0	1	2	2	3	1	5	30
1900....	0	4	3	2	2	8	3	0	4	4	1	3	34
1901....	6	3	3	1	1	1	0	4	6	2	1	3	31
1902....	5	7	6	5	4	7	4	2	0	3	6	1	50
1903....	3	4	2	2	1	2	2	5	5	3	2	2	33
1904....	4	4	7	4	6	1	2	4	4	1	3	4	44
1905....	6	6	9	10	3	7	4	4	3	2	4	2	60
1906....	5	6	7	6	5	4	4	4	2	4	1	1	49
1907....	3	7	5	5	4	4	1	4	0	0	1	1	35
1908....	5	7	12	4	6	3	2	5	6	2	3	5	60
1909....	5	3	6	6	7	8	5	8	4	2	2	6	62
1910....	4	8	5	6	5	3	2	3	2	3	3	5	49
Mean..	4.5	4.9	5.9	4.3	4.1	3.8	2.7	3.0	2.8	2.3	2.3	3.8	

LUNAR HALOS.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1891....	3	2	3	1	1	0	0	1	1	0	0	1	13
1892....	5	1	1	3	1	1	2	0	1	0	1	2	18
1893....	1	1	3	1	1	0	0	0	1	2	0	1	11
1894....	1	4	2	3	1	0	0	0	0	2	0	2	15
1895....	2	3	2	2	2	0	0	0	0	3	2	1	17
1896....	3	3	0	2	1	0	0	0	0	1	6	3	19
1897....	5	1	4	2	1	0	0	0	1	1	1	2	18
1898....	5	2	3	0	2	0	0	1	0	1	2	7	23
1899....	3	2	1	0	0	0	0	1	2	0	3	4	16
1900....	1	2	2	0	1	1	1	0	0	1	2	1	12
1901....	1	3	0	1	0	0	0	1	1	1	1	1	10
1902....	2	1	1	3	0	0	0	0	0	0	2	0	9
1903....	2	1	1	1	0	0	0	0	1	1	2	2	11
1904....	2	0	1	2	1	0	0	1	0	0	4	1	12
1905....	2	3	1	1	2	0	0	0	0	1	1	0	11
1906....	3	1	3	1	3	1	2	2	1	3	0	0	20
1907....	6	0	3	3	3	0	0	3	0	2	1	3	24
1908....	4	5	1	1	1	2	1	0	2	0	3	4	24
1909....	2	1	4	1	0	3	0	0	1	0	2	2	16
1910....	1	4	4	1	1	3	2	1	0	2	1	2	22
Mean..	2.7	2.0	2.0	1.5	1.1	0.6	0.4	0.6	0.6	1.1	1.7	2.0	

Certain other facts must be considered in this connection, however. In the latitude of the observatory (lat. 42° 13′ N., long. 71° 7′ W. of Greenwich) the sun is above the horizon about 6 hours longer in June than it is in December, thus increasing by about 67 per cent the time when solar halos may occur. Cyclones are more frequent and hence cirro-stratus clouds are more common in winter than in summer. The relatively small number of solar halos in summer as compared with the number in winter seems to indicate, when these facts are kept in mind, that the conditions favoring their formation are very much less frequent then. On the other hand, since the nights are longer in winter than in summer more lunar halos are theoretically possible during that half-year. Moreover, lunar halos are also related to the age of the moon, since the latter must usually be in a phase between first and last quarter in order to give sufficient light to produce a halo. Partly for this reason, the total number of solar halos in a year is more than twice that of lunar halos. As may be learned from the table, few months occur in which no solar halos are observed while sometimes as many as 12 are seen, as was the case in March, 1908. During the 20 years the total number of solar halos per year ranged from 30 in 1899 to 62 in 1895 and 1909. Lunar halos are not observed every month, though as many as 7 were seen in one month, December, 1898. During the period considered the number per year varied from 9 in 1902 to 24 in 1907 and 1908. Halos vary greatly in the duration of their existence, some lasting but a few minutes, while others continue for many hours. A solar halo was observed to persist for 10 hours, while on several occasions a lunar halo observed in the evening was still visible early the next morning, doubtless having continued all night. Based upon the records for the 10 years 1901 to 1910, inclusive, the average duration of halos in hours for each month of the year at Blue Hill is as follows:

TABLE 2.—*Average duration (in hours) of halos for each month.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Solar halos...	1.6	2.2	2.2	2.3	1.9	1.9	1.9	2.2	2.4	1.9	1.1	1.7	1.9
Lunar halos..	1.3	1.8	1.8	1.9	1.3	1.3	.....	1.7	2.3	1.6	1.8	1.5	1.7

In the popular mind considerable attention is given to halos as forerunners of precipitation, frequent references to them occurring in poetry and proverb. Various European studies have been made in this connection, but with the exception of a paper by Mr. George Reeder (6), Section Director of the United States Weather Bureau at Columbia, Mo., no extensive study based upon American data has been made. After examining the record of halos observed at Columbia, Mo., during 1905 and 1906, Mr. Reeder concluded that (*a*) "halos are a very good guide in predicting weather changes, especially the 22-degree circles;" (*b*) the 22-degree circle is followed by precipitation usually within 12 to 18 hours, the storm center crossing the meridian near the point of observation; and (*c*) "when the 45-degree circle is observed the storm center is usually from 800 to 1,000 miles or more away, and precedes precipitation, if any, by 24 to 36 hours." He has also observed well-defined 45-degree solar halos on occasions when a West Indian hurricane was immediately off or near the east Gulf or South Atlantic States.

The relation of halos to precipitation as shown by the data obtained at Blue Hill Observatory during the 10 years 1901 to 1910, inclusive, is summarized in Table 3. Considering solar halos first, it is apparent that with the exception of one month, July, more than half are followed by precipitation within 36 hours. During the winter months, December to April, inclusive, more than 70 per cent of the solar halos are followed by precipitation, the highest proportion being that of January, with 76 per

cent. Some halos are preceded but not followed by precipitation within 36 hours. The largest number of these occur during the summer half-year, 24 per cent of those occurring in October falling within this class. Moreover, some halos are neither preceded nor followed by precipitation within 36 hours, the greater number of these again occurring during the summer half-year, one-third of the July halos being of this type. The average interval between the appearance of a solar halo and precipitation, when it follows, is longer in summer than in winter. Generalizations regarding lunar halos, on the basis of the data studied, are not so well established, since a relatively small number were available. Only those lunar halos were considered which occurred upon days when no solar halos were seen. Generally speaking, however, lunar halos show conditions not greatly unlike those associated with solar halos.

The apparent close relationship existing between halos and precipitation can be easily explained from a study of cloud distribution in cyclones. Long-continued observations have established the fact that when no low clouds are present a halo is formed (*a*) whenever a thin stratum of cirro-stratus cloud exists in that part of the sky where the sun or the moon is visible, or (*b*) occasionally with high cirrus clouds in which the streamers are sufficiently dense or are matted to produce the stratus effect, the halo in this case being broken or incomplete. The study of halos, therefore, resolves itself largely into a study of cirrus and cirro-stratus clouds. Because of their infrequent occurrence, cirro-stratus clouds in anticyclones are not considered here. For the same reason cirro-stratus clouds associated with thunderstorms are not referred to. Figure 1 shows the distribution of clouds in a cyclone central at Blue Hill, based upon the observations made

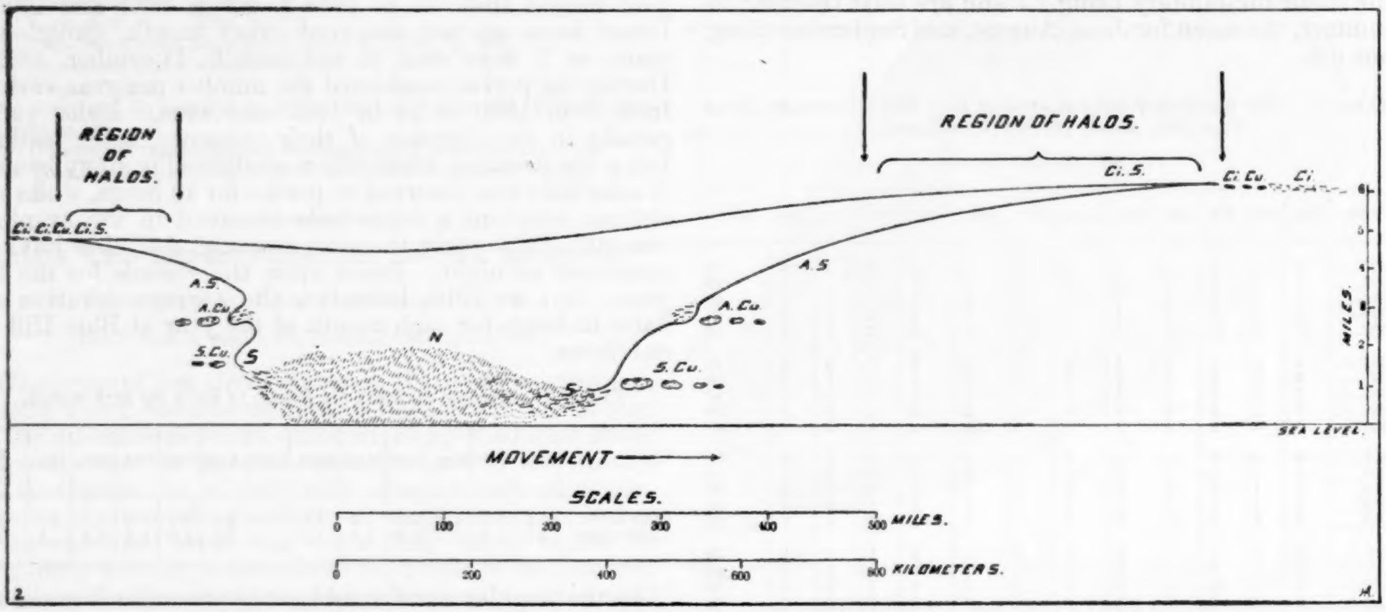

FIG. 2.—Longitudinal section of a typical Northern Hemisphere cyclone, showing regions of halos. (International cloud notation.)

TABLE 3.—*Relations of occurrence of halos to occurrence of precipitation at Blue Hill Observatory for the 10 years 1901–1910.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total and means.
SOLAR HALOS.													
Total number considered....	45	53	59	50	43	41	27	41	32	21	26	29	467
Proportion followed by precipitation within 36 hours (per cent)................	76	74	71	74	63	68	48	68	59	62	69	72	69
Proportion preceded but not followed by precipitation within 36 hours (per cent).	6	7	17	8	21	17	19	10	16	24	10	11	12
Proportion neither preceded nor followed by precipitation within 36 hours (per cent)................	18	19	12	18	16	15	33	22	25	14	21	17	19
Average number of hours between halo and precipitation....	15.4	13.8	14.1	16.0	16.8	16.8	*12.8*	18.9	16.4	17.0	14.6	13.5	15.6
LUNAR HALOS.													
Total number considered....	20	9	13	6	6	3	4	5	3	9	11	13	102
Proportion followed by precipitation within 36 hours (per cent)................	60	44	62	100	83	0	75	40	67	33	64	62	60
Proportion preceded but not followed by precipitation within 36 hours (per cent).	30	56	23	0	17	33	0	20	33	22	27	23	26
Proportion neither preceded nor followed by precipitation within 36 hours (per cent)................	10	0	15	0	0	67	25	40	0	45	9	15	16
Average number of hours between halo and precipitation....	14.2	16.0	18.2	14.8	19.6	....	....	....	....	....	14.1	*11.1*	15.4

at the observatory in 1890–1891(7). The large ring of cirrus and cirro-stratus cloud covers an area about as large as the remainder of the cyclone. In this large territory, where a halo is everywhere visible when the sun or the moon is above the horizon, the cloud and the halo are the only visible evidences of the cyclone. If the observer is in the forward part of this ring he will find that as the hours pass the cirrus cloud first seen changes to cirro-stratus, the halo disappears when the latter in turn is obscured by the lower alto-cumulus and alto-stratus. The latter stratum is subsequently obscured by still lower stratus and strato-cumulus cloud, and precipitation begins soon afterwards. The transition is faster in winter than in summer, since storms, the upper winds, and the clouds are accelerated in movement then. This explains the shorter interval between halos and precipitation in winter than in summer. If the observer is in a position of the ring to the right or to the left of the path of the moving cyclone the halo persists longer than usual, and it is neither preceded nor followed by precipitation. This explains the cases of this kind included in the summary. Moreover, the summary also shows a few halos in which precipitation precedes but does not follow within the time limits designated. This condition would be represented by that part of the ring at the rear of the cyclone center, the precipitation having gone before the halo, and the fair weather of the anticyclone following. It should be borne in mind that the cloud distribution

shown in the diagram is that of a typical cyclone, and though based upon a great number of observations it does not necessarily represent the conditions accompanying every individual cyclone.

Based upon the cloud observations made at Blue Hill Observatory during 1890–1891, the percentage frequency of precipitation following cirro-stratus cloud is as follows(7):

TABLE 4.—*Frequency of precipitation following cirro-stratus, at Blue Hill Observatory.*

Cirro-stratus moving from	S.	SW.	W.	NW.
Precipitation frequency (per cent)	60	42	55	62
Departure from normal (per cent)	+24	+6	+19	+26

The departure from the normal shows how much more frequently precipitation follows cirro-stratus cloud than is indicated by the average probability of rain regardless of cloud. Cirro-stratus cloud moving from an easterly point is a rare phenomenon at Blue Hill, only 8 out of 239 observations during that year showing such movement.

While Figure 1 may be regarded as a projection upon the ground of the cloud areas in a cyclone, Figure 2 may be considered as a longitudinal section along a major axis through the center of a typical storm, and hence parallel to the direction of movement (7). In this diagram the vertical dimension is not directly comparable with the horizontal dimension, since the typical storm represented is, in round numbers, 10 to 13 kilometers (6 to 8 miles) in depth, 2,400 to 4,800 kilometers (1,500 to 3,000 miles) in length, and 1,600 to 2,400 kilometers (1,000 to 1,500 miles) in breadth. The storm as shown in the diagram is supposed to move from left to right. The sequence of conditions often noted at Blue Hill Observatory is as follows: Cirrus streamers accompanied by scattered cirro-cumulus clouds give the first warning of the approach of a storm, and often appear before the barometer begins to fall. Soon the cirrus becomes denser and cirro-stratus cloud is formed, a halo appearing if the sun or the moon is favorably located. The barometer begins to fall about this time, the wind goes around to a southerly point and the temperature rises.

The cloud stratum becomes thicker and lower, and the halo disappears when the clouds change to alto-stratus and alto-cumulus. The clouds become denser and darker, the wind veers to an easterly point and increases in velocity, the humidity rises, and the barometer continues to fall sharply. Low fracto-stratus and fracto-nimbus clouds appear and precipitation begins after a short time. The duration of the rain varies greatly for the various storms, often being but a few hours in winter, while it may last for several days in summer when the storms move slowly. After precipitation ceases the sequence of events which preceded it is repeated, but in the reverse order and at an accelerated rate. The dark nimbus cloud gives way to the lighter stratus and strato-cumulus, the wind shifts to northwest and increases in velocity, the barometer rises, and the temperature and humidity fall. Later the clouds become the higher alto-stratus and alto-cumulus, which are soon replaced by cirro-stratus, which again shows a short-lived halo if the sun or the moon is above the horizon. As the storm passes out to sea in a northeastward

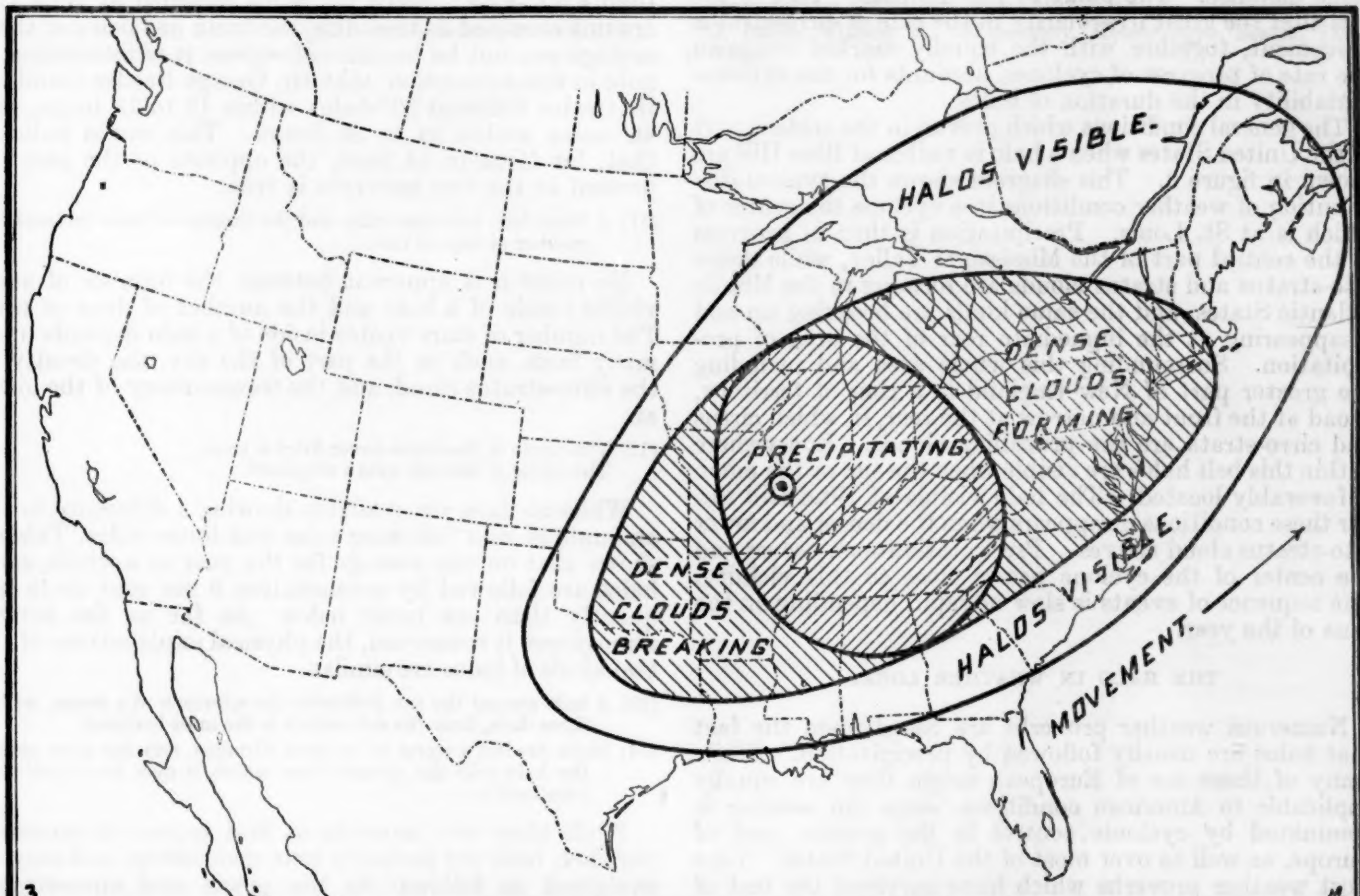

FIG. 3.—Sky conditions surrounding a typical cyclone, showing regions where halos may form. ○ center of cyclone.

direction cirrus and cirro-cumulus clouds linger for a time as a last reminder. Usually an anticyclone follows with clearing skies, light variable winds, clear cool air, low humidity, and accelerated radiation accompanying the relatively high pressure.

The mean horizontal velocity of the cirro-stratus cloud in which the halos are usually formed is 35.8 meters per second. The mean for April to September, inclusive, is 30.0 meters per second, while that for October to March, inclusive, is 41.7 meters per second. A maximum velocity of 94 meters per second was observed, while the minimum was but 0.5 meter per second, both of these, strange to say, occurring in the month of February. In the front of a cyclone the wind at the cirro-stratus level is apparently blowing at a considerably higher rate than it does at the same level in an anticyclone when cloud is not present. While the mean velocity of the cirro-stratus cloud during the summer half-year is 30 meters per second, that for the wind at the same level in the clear air of an anticyclone is but 18 meters per second, as indicated by observations of pilot balloons made at the observatory. The mean velocity of progression of cyclones for the United States in meters per second, as determined by Loomis (**8**), is as follows:

January	15.1	May	11.4	September	11.0
February	15.3	June	10.9	October	12.3
March	14.1	July	11.0	November	13.3
April	12.3	August	10.1	December	14.9
				Mean	12.7

However, cyclones have sometimes traveled from western Kansas to the vicinity of Blue Hill in a single night, while others have required four days to travel over the same distance. The point to be emphasized here is the fact that the great irregularity in the rate of cirro-stratus movement, together with the equally marked range in the rate of progress of cyclones, accounts for the extreme variability in the duration of halos.

The general conditions which prevail in the eastern part of the United States when a halo is visible at Blue Hill are shown in figure 3. This diagram shows the typical distribution of weather conditions in a cyclone the center of which is at St. Louis. Precipitation is then in progress in the central part of the Mississippi Valley, while dense alto-stratus and stratus clouds are forming in the Middle Atlantic States, and the same kinds are breaking up and disappearing at the immediate rear of the area of precipitation. Surrounding this whole area and including the greater part of New England is a ring of territory, broad at the front and narrow at the rear, in which cirrus and cirro-strata are the prevailing clouds. Everywhere within this belt halos are visible when the sun or the moon is favorably located. The halo visible at Blue Hill under these conditions disappears when the denser and lower alto-stratus cloud arrives. Precipitation soon occurs and the center of the cyclone passes close to this vicinity. The sequence of events is slow or rapid depending on the time of the year.

THE HALO IN WEATHER LORE.

Numerous weather proverbs are based upon the fact that halos are usually followed by precipitation. While many of these are of European origin they are equally applicable to American conditions, since the weather is dominated by cyclonic control in the greater part of Europe, as well as over most of the United States. Like most weather proverbs which have survived the test of time, they are expressions of scientific principles, but their origin is probably explained by the similar observations of many people, rather than by deductive scientific reasoning. The following proverbs have been gleaned from various books of weather lore, and are given in the forms in which they have appeared in print:

(1) The moon with a circle brings water in her beak.

(2) When the sun is in his house it will rain soon.—(Zuñi Indians.)

(3) When round the moon there is a "brugh,"
The weather will be cold and rough.—(Scotland.)

(4) For I fear a hurricane;
Last night the moon had a golden rim,
And to-night no moon I see.—(Longfellow, "The Wreck of the Hesperus.")

(5) The moon in halos hid her head,
The boding shepherd heaves a sigh.

(6) If two parhelia occur, one towards the south, the other towards the north, with a halo round the sun, they indicate rain within a short time.—(Theophrastus.)

(7) When the fourth day around her orb is spread
A circling ring of deep and murky red,
Soon from his cave the God of Storms will rise,
Dashing with foamy waves the lowering skies.—Aratus (J. Lamb).

(8) No weather fair expect, when Iris throws
Around the azure vault two painted bows;
When a bright star in night's blue vault is found
Like a small sun by circling halo bound.—Aratus (J. Lamb).

These first eight proverbs are generalizations embodying the principle that halos are usually followed by precipitation within a short time.

(9) When the wheel is far, the storm is n'ar;
When the wheel is near, the storm is far.

(10) Circle near, water far;
Circle far, water near.—(Italy.)

The next two proverbs refer to the size of the halo and state, in other words, that rain follows a 46°-halo sooner than a 22°-halo. Since the halos recorded at Blue Hill are not classified as to radius, the truth or falsity of these sayings can not be tested. However, it is interesting to note in this connection that Mr. George Reeder found (**6**) that rains followed 22°-halos within 12 to 18 hours, and 46°-halos within 24 to 36 hours. This would indicate that, for Missouri at least, the opposite of the idea expressed in the two proverbs is true.

(11) A lunar halo indicates rain, and the number of stars inclosed the number of days of rain.

No relation is apparent between the number of stars visible inside of a halo and the number of days of rain. The number of stars visible inside of a halo depends upon many facts, such as the part of the sky, the density of the cirro-stratus cloud, and the transparency of the lower air.

(12) The circle of the moon never filled a pond,
The circle of the sun wets a shepherd.

While no data are available showing a difference in the amounts of rain following solar and lunar halos, Table 3 shows that on the average for the year as a whole, solar halos are followed by precipitation 9 per cent more frequently than are lunar halos. As far as the earth's atmosphere is concerned, the physical explanations of the two kinds of halos are similar.

(13) A halo around the sun indicates the approach of a storm, within three days, from the side which is the most brilliant.

(14) Halos predict a storm at no great distance, and the open side of the halo tells the quarter from which it may be expected.—(Scotland.)

While these two proverbs at first appear to express a paradox, both are probably true statements, and may be explained as follows: As the cirrus and cirro-stratus fronds push across the sky in the region of the sun the halo first appears and subsequently becomes brighest in

that part of the arc from which the cyclone is approaching. Later the halo becomes complete and the light is homogeneous throughout. As the storm advances, altostratus cloud arrives and obliterates the original and for a time the brighest part of the halo, that is, the side nearest the oncoming storm. Both proverbs are true generalizations but refer to different times in the life history of the halo.

(15) Double or treble circles round the moon foreshadows rough and severe storms, and much more so if these circles are not pure and entire, but are spotted and broken.—(Bacon.)

When halos are double or treble it signifies that the cirro-stratus cloud is relatively thick, such as is likely to be the case in a deep and hence well-developed storm. Broken halos indicate a much disturbed state in the upper air, with precipitation near at hand.

(16) If there be a ring or halo around the sun in bad weather, expect fine weather soon.

(17) If the rising sun be encompassed with an iris or circle of white clouds and they equally fly away, this is a sign of fair weather.—(Pliny.)

(18) If the sun or moon outshines the "brugh," bad weather will not come.

These three proverbs may refer to the halo often observed at the rear of a cyclone, and belong to the type referred to in Table 2, as halos preceded but not followed by precipitation. Or they may refer to a halo on either side of the path of the precipitation area, this type of halo being neither preceded nor followed by precipitation.

(19) A halo round the moon is a sign of wind.—(China.)

(20) A circle or halo round the moon signifies rain rather than wind, unless the moon stand erect within the ring, when both are portended.—(Bacon.)

(21) A white ring round the sun towards sunset portends a slight gale the same night; but if the ring be dark or tawny, there will be a high wind the next day.—(Bacon.)

(22) If there be a circle round the sun at rising, expect wind from the quarter where the circle first begins to break; but if the whole circle disperses evenly there will be fine weather.—(Bacon.)

In the present study the relation between halos and wind was not investigated. However, the four proverbs referring to wind seem to be applicable to the wind at the rear of a cyclone which usually accompanies the clearing conditions following precipitation.

(23) A halo oft fair Cynthia's face surrounds,
With single, double, or with triple bounds:
If with one ring, and broken it appear,
Sailors, beware! the driving gale is near.
Unbroken if it vanisheth away—
Serene the air, and smooth the tranquil sea.
The double halo boisterous weather brings,
And furious tempests follow triple rings.
These signs from Cynthia's varying orb arise—
Forewarn the prudent, and direct the wise.
—Aratus (J. Lamb).

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SECTION II.—GENERAL METEOROLOGY.

THE MICROBIC CONTENT OF INDOOR AND OUTDOOR AIR.

By C.-E. A. WINSLOW, Chairman, & W. W. BROWNE, Bacteriologist.

[Dated, New York State Commission on Ventilation, Aug. 13, 1914.]

Determinations of the microbic content of the atmosphere have been reported by many observers since the first studies made by Pasteur along this line, yet the results have never been correlated and systematized so as to furnish standards which could be accepted as representing normal values for air from different sources. The New York State Commission on Ventilation, whose researches are supported by a generous gift from Mrs. Elizabeth Milbank Anderson, made through the New York Association for Improving the Condition of the Poor, decided that one of its tasks must be to digest the mass of published data upon this subject and to carry on such original work as might be necessary to establish such normal values for the microbic content of the atmosphere as are now at hand for its chemical constituents. The results of the new work of the commission along this line are briefly presented here.

A total of 353 samples of air were examined during the first six months of the present year, obtained from four different groups of sources, which we have classed under the headings: Country, City, Offices, and Factories. The samples of "Country air" (85 in number) were collected in woods and fields, on country roads and over water in suburban districts near New York City. The "City air" (134 samples) was obtained in the streets of New York City itself. The "Office" samples came from three different sources: Nineteen of them from a commercial office in downtown New York, 49 from a large commercial establishment on West Twenty-third Street, New York, and 19 from the United States Senate Chamber, Washington, D. C.—87 in all. Of the 47 "Factory" samples, 25 came from a cigar factory and 22 from a hat factory in New York City, representing crowded and somewhat dusty trades.

The samples of air were collected and examined by the methods prescribed by the Committee on Standard Methods for the Examination of Air of the American Public Health Association.[1] In each case 5 cubic feet of air were drawn through a 1-centimeter layer of 80-mesh sand by means either of a hand pump or of the ingenious air-sampling pump made by Wallace and Tiernan of New York and used by Prof. Charles Baskerville and the senior author in their study of air conditions in New York City schools.[2] On returning to the laboratory the microbes collected in the sand were washed out by shaking the sand up in 10 cc. of water and aliquot portions of the water were plated in the usual manner.

The results of the first determination made, the count of microbes developing on gelatin at 20° C. in 4 days, are summarized in Table 1. The results of the study of New York schoolroom air by Profs. Baskerville and Winslow are also included for comparison, since the methods used are identical.

[1] American Journal of Public Health, 3: 78.
[2] Report of the Committee on School Inquiry, Board of Estimate and Apportionment, City of New York, 3: 1911-1913.

TABLE 1.—*Microbes in air from various sources (gelatin, 20° C.).*

[Percentage of samples in each case.]

Number of microbes per cubic foot.	0–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	351–375	376–400	Over 400
Country	44	25	11	7	7	3	...	...	1	2	...	...	...	...	...	1	...
City	28	24	16	6	8	4	3	1	2	2	3	...	...	...	1	...	2
Offices	42	23	9	2	4	2	2	4	1	1	...	1	...	1	1	...	4
Factories	12	15	20	6	29	3	...	6	...	...	...	3	3	3	...	...	3
Schools	24	17	14	13	10	7	4	2	2	2	1	1	1	...	...	...	2

It will be noted that we have called the organisms found "microbes" and not bacteria. Many observers have distinguished, by the appearance of the colonies, between molds and bacteria. Many mold colonies are, of course, clearly recognizable, but we are inclined to believe that in other cases the distinction can not be made by the eye alone and we have therefore grouped them all together.

The maximum counts recorded, and the only ones over 500, were counts of 700, 705, and 735, all in the business offices. The average for country air was 56; for city street air, 72; for offices, 94; for factories, 113; and for schools, 96.

The country air is evidently freer from microbic life than that of the city streets, and the factory air has clearly the largest content. The offices and schools show an average between the last two, but in the case of the offices it should be noted that the average is the result of a number of low values and a few excessively high ones.

In addition to this determination of the microbes that will develop at 20° C. we also made a count upon litmus-lactose-agar at 37° C. to get the microbes capable of development at body temperature, which would include bacteria from the human mouth. The ratio between the 20°- and the 37°-count is known to be significant in water examinations where a high ratio suggests sewage pollution, but very little is known of this ratio in air. The results of our examinations are indicated in Table 2.

TABLE 2.—*Microbes in air from various sources (lactose-litmus-agar, 37° C.).*

[Percentage of samples in each case.]

Number microbes per cubic feet.	0–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	351–375	Over 400
Country	72	13	5	4	...	1	...	1	...	1	...	...	1	...	...	1
City	60	22	12	3	1	...	...	1	1	1	...	...	...	1	...	...
Offices	64	13	2	5	6	1	1	...	...	3	...	...	...	...	1	5
Factories	49	23	6	11	3	6	...	...	...	...	...	...	...	...	...	3

Four of the counts recorded were over 500; one of 5,200 was in the country; two of 1,070 and 1,647, respectively, were in one of the commercial offices, and one of 885 was in the cigar factory.

The average value for the country air was 30 microbes per cubic foot; for the city streets, 32; for the offices, 80;

and for the factories, 63. As before, the country air is distinctly freer from microbic life than the atmosphere of the city, although a single high value for the country brings their general averages close together. The factory air is higher in content than any other group, so far as the general distribution of results is concerned. The office samples, as before, show many very low and a few very high counts, the latter bringing the average up above even that for factories.

The ratio of the 37°-count to the 20°-count was about 1 to 1.9 for country air, 1 to 2.4 for city air, 1 to 1.2 for the offices, and 1 to 1.8 for the factories. All these ratios are high in comparison with those we find in water of good quality.

Finally, we made an estimate of the number of mouth streptococci present by isolating pure cultures from any colonies characteristic of this group upon the litmus-lactose-agar plates and studying their morphology and fermentation reactions. The lactose fermenting organisms when found in air appear to be chiefly derived from the human mouth and to be reasonably good indices of mouth pollution of the atmosphere. The results of this study are indicated in Table 3 with a summary of the 20° and 37° averages previously discussed.

TABLE 3.—*Average microbic content of the air from various sources.*

Samples.		Microbes per cubic foot.		Streptococci per 100 cubic feet.
Source.	Number.	20° C.	37° C.	
Country	85	56	30	12
City	134	72	32	11
Offices	87	94	80	22
Factories	47	113	63	43
Schools	684	96	....	30

So far as the presence of mouth streptococci is concerned, there is a clear distinction between outdoor and indoor air, the former having less than half as many streptococci as the latter, while the factory air is more polluted than the air of the offices and schools.

Conclusions.

In general it may be concluded from this survey of the microbic content of 353 samples of air from various sources that:

1. The number of microbes developing at 20° C. from outdoor air in suburban districts is generally under 50 per cubic foot and rarely over 100.

The count at 37° C. for such air is about half that at 20° C. and rarely over 50 per cubic foot. The number of mouth streptococci in such air is small—in the neighborhood of 10 per 100 cubic feet. The air from more remote regions would no doubt show still smaller numbers.

2. The air of city streets shows a slightly higher number of microbes, but the general relations are much the same in all the respects noted above.

3. The air of occupied spaces shows, as might be expected, larger average numbers of bacteria and much greater fluctuations. The 20°-count may average over 100 microbes per cubic foot, as in the factories studied, and may reach 700 or more, as in some of the offices. The 37°-count averaged over 50 both in factories and offices and was nearly as high as the 20°-count in the latter case. A few very high 37°-counts were obtained, two between 1,000 and 2,000 in offices, and one of 5,200 in the country, the latter clearly abnormal. Mouth streptococci are much more abundant in indoor air, ranging from 20 to 40 per 100 cubic feet of air, and the results bear out the conclusion that the number of these organisms furnishes a good measure of mouth pollution due to concentration of population in confined spaces.

THEORETICAL METEOROLOGY: MORE PARTICULARLY THE THERMODYNAMICS OF THE ATMOSPHERE.

[Communicated to the International Meteorological Congress at Chicago, Ill., August, 1893.]

By PROF. DR. WILHELM VON BEZOLD.

[Dated: Kgl. Preussisches Meteorologisches Institut, Berlin, July 12, 1893.]

[The late Wilhelm von Bezold was born June 21, 1837, at Munich, and died at Berlin on February 17, 1907, at the age of 69. At the time of his death he was director of the Royal Prussian Meteorological Institute and professor of meteorology in the University of Berlin, a position he had held since 1885. From 1868 to 1885 he was professor of physics in the Technische Hochschule at Munich, Bavaria, where he had also been actively engaged from 1879 to 1885 in organizing and directing the Bavarian meteorological réseau and service. A brief notice of his work is given in the MONTHLY WEATHER REVIEW for February, 1907, **35**:73.

The present paper was prepared for publication between 1901 and 1912, but publication has been delayed for the reasons stated in the MONTHLY WEATHER REVIEW for February, 1914, **42**:93.]

Strictly speaking, theoretical meteorology—except meteorological optics and the study of atmospheric electricity—is nothing but a most complicated hydrodynamic and thermodynamic problem.

The condition existing at a certain point of the atmosphere at any given moment is fully determined by the pressure of the air, its temperature, the amount and character of the moisture contained in a unit of volume, and the direction and velocity of motion.

If these elements are also given for neighboring points of space, or specially the changes that occur in the passage from a given place to another adjoining it, and if one also knows the amount of heat that is added to or abstracted from the particle of the atmosphere under consideration in a unit of time, then one has all the elements that determine the change in the given conditions of the air. If it were possible to unite these quantities in an equation it would be regarded as the fundamental equation of the whole of the theoretical meteorology.

However, even if one should succeed in formulating it, this equation could never attain a practical value, since it would be so involved that a discussion of it would be attended with the greatest difficulties. It would at all events be necessary to subsequently introduce most extensive simplifications and then to disregard first one and then another of the variables occurring in it. Therefore, it has not yet been even attempted to attack the problem from so general a point of view but rather to follow the opposite path. Special cases have been selected in which sometimes one and sometimes another group of the elements above enumerated have been omitted from consideration, and thus the great problem has been resolved into separate problems and general theoretical meteorology has been treated in separate sections.

In this manner the statics and dynamics of the atmosphere, as well as the thermodynamics, have been developed as disconnected studies. This separation is not based on the nature of the subject but is rather only a consequence of the impossibility of attacking the problem in its complete generality. It is precisely because this separation has no natural basis that it introduces many impossibilities, one may even say, dangers. It is

necessary, therefore, to closely examine the hypotheses involved in this analysis into separate studies.

This can be most easily done, as it seems to me, by assuming that the general equation mentioned in the beginning as connecting all the elements is really known and has been formulated. With these assumptions we should only have to equate the velocities and accelerations, as also the increase of heat, each to zero in order to convert that equation into the fundamental equation for the static condition of the atmosphere, i. e., into the barometric formula.

Assume, as above, that there is no increase or loss of heat, that the changes of temperature due to compression or expansion need not be taken into account, and that no change of aggregation takes place in the water that is mixed with the air; then when we express the relations between the distribution of pressure, velocity, and acceleration, we should attain the dynamics of the atmosphere in the ordinary sense of the word.

Thus it is seen that the hypotheses made in this case are by no means of so harmless a nature as those which underlie the hypotheses of statics in the atmosphere. The assumption that velocities and accelerations are equal to zero—that is to say, that equilibrium exists—is perfectly admissible; but disregard of the warming by compression is an omission that can not be allowed. It is precisely on account of this and similar assumptions that many investigations into the dynamics of the atmosphere acquire the character of very crude approximations.

It is precisely the enormous difficulties offered by these problems that will oblige us to be content with such approximations for a long time to come; it is, however, important that we should always keep them in mind and if possible estimate the magnitude of the resulting error. The conditions attending the thermodynamic investigations are much more favorable than those attending the study of the dynamics proper of the atmosphere.

In thermodynamics one considers only the relations between pressure, density or specific volume, and moisture, and gain or loss of heat, while the space coordinates of the element of the atmosphere under consideration, as well as its movement, are entirely disregarded. Of these two assumptions the first (neglect of location) is entirely admissible, the latter (neglect of motion) is also admissible on the assumption that the energy of the translatory movement is infinitesimally small in comparison with the amount of heat that is exchanged or converted into work or gained by work, and in the majority of cases to be considered, this second condition is satisfied to a high degree of accuracy.

Hence it follows also that the thermodynamic processes in ascending and descending air currents may be investigated without considering the velocity of the current, because the energy of this latter is exceedingly small in comparison with the work of expansion or compression to be done by the ascent or descent. The results obtained in these investigations hold good, therefore, without considering whether the expansion or compression are actual consequences of an ascent or descent, or whether they are produced by some other cause.

Moreover, this last-named point shows that the division of the general problem into special problems, as made necessary by the complicity or the subdivision of the whole subject into separate studies, also has its own peculiar advantages. Had the problem of the cooling or warming of the ascending and descending currents of air always oeen regarded from a purely thermodynamic point of view without previously introducing the altitudes into the computation, we could never have fallen into the error of regarding the cooling of the ascending current as a consequence of the work expended in raising the mass of air—work which, in reality, is performed by other air masses that are sinking in other places.

Again, with a purely thermodynamic treatment of these questions it would not have escaped our attention that, in the so-called adiabatic expansion of moist air, from the very beginning of condensation onward we have in general no longer to do with adiabatic changes of condition in the ordinary sense of that term. Properly speaking, adiabatic changes occur only so long as all the water originally present is carried along with the air; as soon as some of the water falls as rain an important change of condition occurs. For whereas in the reversible changes of condition ordinarily considered that occur without gain or loss of heat, the entropy remains unchanged; on the other hand, this is not true in the case of the formation of precipitation by the so-called adiabatic expansion. In the latter case one has to deal with processes that are indeed reversible in the very smallest parts and therefore apart from very insignificant corrections, may also be calculated numerically as such—yet are not reversible when considered as a whole.

It is precisely because moist air exhibits this peculiar behavior when in the condensation stage that the cyclic processes of the atmosphere are so essentially distinct from all others that we have been accustomed to consider. Formerly these peculiarities were never emphasized, but they at once became prominent as soon as the cycles in the ascending and descending currents began to be studied from a purely thermodynamic standpoint.

From these examples it may be seen how well founded is the assertion made above that the analysis of theoretical meteorology into separate studies, although only an expression of our inability, offers also certain advantages.

However, in order to profit by these advantages, it is necessary to make this subdivision as discreetly as possible, and to deduce as completely as possible all the consequences that can be drawn under definite simplifying hypotheses. It is only when this is accomplished that we should try to discover how matters shape up as we gradually begin to take into account the elements that were at first neglected. In this manner connecting bridges are built between the separate branches of our subject. Often this is accomplished, to a certain extent, spontaneously since it suffices to simply observe from a new standpoint the results previously obtained under certain other assumptions.

I will exemplify this by showing how the purely thermodynamic study of the cyclic processes of the atmosphere leads to important conclusions in regard to the general circulation of the atmosphere.

The entire circulation of the atmosphere depends upon great cycles. The air rises at some point, and only after passing through the most varied conditions—after giving and receiving both heat and water—finally descends, and after still further changes of condition begins the process over again. In order to show all these changes clearly and not to lose the guiding thread of these considerations, it is best to represent the changes graphically. This method is as advantageous in the execution of theoretical investigations in order to clearly present the formulæ and trains of thought, as it is in presenting and discussing the material obtained from observation.

In thus utilizing graphic methods one may employ the method or presentation adopted by H. Hertz, or the more general method of Clapeyron, as I myself showed in those days. It must, however, be borne in mind that the curves drawn by the Watts indicator are nothing but diagrams

drawn according to the Clapeyron method. Of these two methods of presentation, the former is better adapted for graphic computations, while the latter offers special advantages for theoretical investigations. On the other hand, both methods have one defect which is, indeed, of only very minor fundamental importance, but which may yet be found annoying by those who have had little experience in considerations of this kind.

This defect arises from the fact that in both of these methods the changes of condition experienced by an ascending mass of air are represented by falling curves and those of a descending mass of air by rising curves. This, however, is a difficulty that can easily be overcome by changing the coördinates, as has already been done by Prof. William M. Davis for the Hertzian diagrams.

I will, however, here assume that the more generalized Clapeyron method is employed in its usual form; that is to say, the volume is represented by the abscissæ and the pressure by the ordinates. If we represent a cycle by this method, then, as is well known, the areas of the surfaces inclosed by the diagram are a measure of the work done or consumed. In the extension of this theorem, as used by me, the simple diagram is replaced by the projection of the space-curve representing the change in condition, and hereafter I shall refer to this projection briefly as the diagram.

The question whether in this process work is done or consumed, can be answered at once from the direction along which the curve is traversed. If the change in condition proceeds in such a way that the diagram inclosing the surface is traversed in a clockwise direction, then heat is consumed and by this process work is gained; in the opposite case, work is consumed and heat is gained. Therefore in any atmospheric cycle, e. g., in the exchange of air between cyclone and anticyclone, it suffices to enter in the diagram the actually observed values of the pressure and volume (or what amounts to the same thing, the values of pressure and temperature) in order to at once recognize whether in this process we have to do with a consumption or a gain of heat.

If, for instance, we assume that the atmospheric ascent took place in a summer cyclone in which the temperature is lower than in the attendant anticyclone, then the representative diagram will be traversed in a counter-clockwise direction. In this case, therefore, there is a consumption of work and a gain of heat. But such a process can not possibly contain within itself the germ [or cause] of its existence, since the earth receives energy from without only in the form of heat, which is delivered by the sun at a higher temperature and subsequently radiated from the earth at a lower temperature.

The great atmospheric cycle as conditioned by the general circulation must, therefore, be traversed in an opposite direction to that just described. It must, in fact, be one in which heat is converted into work.

Processes such as that above imagined, although they do seem to correspond to the interchange between cyclone and anticyclone in summer time, are nevertheless never to be explained by the convection theory, but are only conceivable in case the great cycle of the general circulation delivers an excess of mechanical energy in order to develop or sustain smaller processes of the opposite kind.

From this it is clear that even pure thermodynamic considerations may lead to results that are of the greatest importance for the understanding of dynamic processes. Consequently, we recognize that it is a problem of the highest importance to test numerically by means of well-established observations the considerations here set forth. The construction of such diagrams by use of actually observed data would lead to the most far-reaching conclusions.

Of course, it will not be easy to obtain the values for truly closed cycles, since probably only a part of the air that is raised in the cyclone and transported over to the neighboring anticyclone returns again into the same cyclone. Still the classification of temperatures observed at different heights, according to the cyclonal or anticyclonal character of the weather, will be a contribution in this direction.

In this work the data given by observations on mountain tops can, of course, be used only with great caution. The really decisive figures can only be expected from scientific balloon voyages. Among such voyages the most favorable for the investigation of the questions here considered are those in which the ascent takes place in an area of low pressure but the descent in the neighboring anticyclone, or conversely. Then the ascending and descending portions of the curve actually belong together. Such voyages have already been made, but it is of the highest importance that in these voyages numerous observations be obtained, not only during the ascent but also during the descent.

Unfortunately all these investigations suffer from the misfortune that in the atmosphere we have to do, not with masses of air that are subject simply to variations of pressure and gain or loss of heat, but with the fact that mixtures with other masses of air of different temperatures and moistures are always going on at the same time. So long as the amount of moisture remains the same, and we do not leave the dry stage, then the mixture with air of other temperatures acts precisely as if a warming or cooling had occurred, but the case is more complicated when the moisture is variable.

If, in a current of ascending or descending air, the quantity of moisture in a unit mass remains unchanged, then we are justified in supposing that no mixture with other masses of air has taken place. The change in the quantity of moisture, therefore, gives in a certain sense a measure of the degree of mixture with foreign masses of air, but always only under the assumption that it has not left the dry stage.

But these are questions whose thorough explanation would lead us too far. At present it is only necessary to show that from the diagrams of atmospheric cycles constructed from data actually observed, the most important conclusions can be drawn as to the general circulation of the atmosphere. In the construction of these diagrams, however, we need above all a knowledge of the temperature and the moisture at different altitudes in the regions of ascending and descending currents and at different times of the day and the year. Moreover, the investigations should not be confined to processes going on in middle latitudes; they must especially bear upon the great circulation between the region of equatorial calms and the high pressure zones of the "horse" latitudes.

ICE STORMS OF NEW ENGLAND.

A welcome study of the ice storms (verglas; Glatteis) that have been observed over New England and notably at Blue Hill Observatory, Mass., has just come from the pen of Charles F. Brooks.[1]

[1] **Brooks, Charles F.** The ice storms of New England. Cambridge, 1914. 8 p. 2 pl. 4°. (Harvard University publication.) [Reprinted from Annals, Obs. Harv. Coll., v. 73, pt. 1.]

The author finds the following combinations of conditions which may produce ice storms when there is precipitation:

I. Temperature of the air below 0°C.
II. Temperature of the air above 0°C. and
  A. Temperature of the rain below 0°C.
    1. From passing through a stratum of cold air;
    2. From cooling by evaporation in nonsaturated air.
  B. Temperature of the rain above 0°C. and
  Temperature of the objects coated, below 0°C.
    1. Because of residual cold;
    2. From cooling by evaporation in nonsaturated air.

He finds that no heavy ice storm occurs when the temperature of the surface air is above 0°C., and that no considerable ice storm has occurred at Blue Hill, Mass., under such conditions; but the above considerations show it to be not impossible. When the temperature of objects and the temperature of the lower air also is above 0°C., it is clear that even undercooled rain and such ice pellets as may reach the ground will not be able to form an ice coating. When the air is below 0°C., undercooled rain or ice pellets will not adhere in the frozen state to objects at a higher temperature; but the dripping water will freeze into icicles. If the lower air is warmer and the undercooled rain, etc., does succeed in forming an ice coating on previously cooled objects, still the surrounding air will cause the ice coating to melt without forming icicles. Ice storms may occur with a temperature as low as −13°C.; it may rain hard or gently; the wind may be from any direction, a gale or a calm; the temperature may rise, fall, or remain stationary.

The author then presents a diagram showing graphically the vertical and horizontal distribution of temperature conditions as they affected the precipitation that accompanied the storm of January 5–6, 1910, at Blue Hill. It appears from that study that the ice storm lasted about six hours at the valley station (18 meters above sea level) and a little over one hour at the summit (195 meters above sea level), while a neighboring station standing above 400 meters would have experienced no ice storm at all. "Thus local topography has a great effect on the intensity and extent of an ice storm."

Upon inquiring into the distributions of pressure and wind that cause these ice-storm temperature inversions it appears that there are three general wind conditions which produce them:

(1) Warm air arriving over residual cold air (the "southerly" type).

(2) Cold air coming in below while warm air is arriving above (the "northeasterly" type).

(3) Cold air from the north or west pushing in below a rain cloud (the "northwesterly" type).

The ideal conditions for the first type occur when, after the air next the ground has been strongly cooled by radiation during an anticyclone, a cyclone advances rapidly toward New England. The conditions during January 5–6, 1910, already referred to, furnish an excellent illustration. A pronounced anticyclone (1,043 mbars)[2] had been replaced within 24 hours by a cyclone from the west-southwest bringing a large supply of warm, moist air on south winds in front of a trough extending to the Gulf of Mexico.

The ideal conditions for the second type are presented when there is a good supply of warm southern air from an active cyclone in the south at the same time that an anticyclone in the north is supplying cold air. The northeast wind blowing toward the southern cyclone is pushing cold air in under the warm air flowing northward from the eastern portion of the cyclone to the south. Often, however, the undercurrent from the northeast is not cold enough to wholly counteract the warming effect of the south wind overhead, then the temperature may remain stationary or even rise slowly instead of falling. An ice storm of this "northeasterly" type occurred February 19–22, 1898, also on December 23, 1908, and February 9, 1905. In this last case a kite flight at Blue Hill showed the lower wind ESE. with gradually falling temperature (−1° to −2° C.), the valley temperature being a few degrees higher. Up to almost 800 meters the V. T. G. was nearly the normal adiabatic one; but at 885 meters there was an inversion to +0.5° from a minimum of −3° C. at 760 meters. At that level was the base of an arriving warm southeast wind; snow had been falling for the preceding hour and a half. A similar ice storm occurred over all of northern Germany on October 19–21, 1898 (see full account in Das Wetter, Berlin, November, 1898, p. 247–260); but in that case both the northeasterly and the northwesterly types were in progress simultaneously at different levels.

The "northwesterly" type is about the reverse of the first or "southerly" type. The cold air wedges in below while rain is still falling above. The changes in the form of the precipitation occur in the opposite order also. The "wind-shift line," or boundary between two currents having different directions and temperatures, is of common occurrence but its passage is not frequently accompanied by an ice storm. February 15, 1906, presented a representative storm of this type over the United States, although the beginning of the storm belonged to type 2.

Owing to the fact that a single ice storm often falls under two or even three of the types described, we may best classify them according to the positions and movements of the highs and lows producing them. Two large divisions may be made on this basis: *A*. Storms in which anticyclones in the north dominate cyclones on the south; *B*. Storms occurring from cyclones and anticyclones in the usual regular sequence. All the 31 ice storms occurring under conditions *A* were either of type 2 or a combination of types 2 and 3; 11 of these were severe storms.

Most of the ice storms studied occur under conditions *B*, the severe ones being most common when the low comes from the Gulf of Mexico. The following tabulation shows the frequencies of the different types:

	Storms.
1. Southerly type	67
2. Northeasterly type	116
3. Northwesterly type	59

The "northeasterly" type is favored by southern lows and northern highs; the "southerly" type by the low crowding in close behind the high; and the "northwesterly" type comes most frequently when the high arrives close behind the low.

The distribution of ice storms by months was as follows:

January	48
February	46
March	40
April	7
November	10
December	27
Average year	12

The earliest fall storm came on November 8–10, 1894, and the latest spring storm was on April 30, 1909.

Among extraordinary features accompanying different storms at Blue Hill may be mentioned an inversion of 8° C., lasting many hours during the storm of January

[2] The author used the Harvard College notation of absolute units; perhaps in conformity with the ideas put forward by Prof. A. E. Kennelly in this REVIEW, March, 1914, 42: 141, section 3. The editor here adheres to the prevailing international usage among meteorologists, viz, the bar of Bjerknes.

22-23, 1904. During this storm the alternating gusts that affected only the top of the Hill caused simultaneous temperature fluctuations of 5° in either direction, lasting but as many seconds, as though the summit of the Hill were precisely at the waving boundary between the upper warm current and the lower cold current. The week January 12-17, 1909, brought three severe ice storms to the Hill. The kite flight of the 15th occurred between two of these storms and showed a most interesting rapid destruction of the inversion by the advent of the anticyclone, there being an inversion of 6° between 950 m. and 1,050 m. at 11 a. m., by noon the inversion had diminished in strength but doubled its areal extent, and at 4 p. m. it had disappeared. During this time the summit temperature at Blue Hill had remained stationary.

Mr. Brooks concludes as follows:

Regions of strong cyclonic action bringing precipitation and highly variable temperatures seem to be most subject to ice storms. Thus eastern North America and western Europe are particularly susceptible. Toward the continental interiors when cyclones are weaker there is a diminishing frequency of ice storms. In this country, as in Europe, cyclones frequently support an ice storm for a considerable distance across country. For instance, the ice storm of February 21-22, 1913, began in Texas and eventually crossed New England. The storm of January 5, 1910, was reported as causing much damage in New Jersey the morning of January 5.

To forecast these storms for New England is even more uncertain than to forecast rain or snow, for the belt of occurrence is generally narrow. Ice storms may be much more local than snow storms. Predictions must be based on the occurrence of cyclonic and anticyclonic positions favorable for ice storms, and in making forecasts indications of an ice storm already in progress in the West would help. * * *—[C. A., jr.]

AN APPRECIATION.

In the Belgian journal Ciel et Terre (Brussels) for June, 1914, we find published a full-sized official reprint copy of the Daily Weather Map of the Northern Hemisphere for May 1, 1914, as published by the United States Weather Bureau. This reprint serves to illustrate an article by Vandevyver [1] in the same issue of that bulletin, extracts from which are presented below as they will undoubtedly interest American meteorologists at this time.

The map on the back [of the Daily Weather Map of the United States] (in equidistant English projection) seems made especially to delight the meteorologist who aspires always to see things from above, secretly hoping that he may thus more rapidly solve the problems presented by the elements in whose midst we live.

At a glance one may now grasp the situation over the whole Northern Hemisphere as regards cyclones and anticyclones which play, as we know, so important a rôle in the forces of nature, and we see at the same time the distribution of temperatures.

What is particularly interesting to the professional is the day-to-day comparison of these charts; we certainly make no mistake in predicting that this innovation will be productive of discoveries, and that detailed study of these charts will put us on the right track, if not of the real and complex causes of the origins of these variations, at least of the systems to which their movements belong—which will add great weight to the value of the forecasts.

At first glance the notations of the map are a little disconcerting. The fact is that here the C. G. S. system of absolute units has been adopted for the barometric pressures, and the readings are expressed *in bars;* the bar corresponding to a force of 10 dynes (1,000 millibars being equal to 29.53 inches, or 750.06 mm. of the normal mercury column), and the temperature is given in terms of the absolute zero, −273° C.

It goes without saying that, from a strictly scientific standpoint, one can but approve of the adoption of these units; but in consideration of the fact that, on the one hand, the very young science of meteorology must be made to appeal to all its well-wishers (and for this very reason must reach out beyond the limited circle of the profession) and on the other hand, in view of the wide distribution planned for this chart, it is not a priori clear what advantage is to be gained by thus breaking away from the deeply rooted customs of the general public.

Except for this gentle criticism, which is, moreover, but an expression of a personal opinion and detracts nothing from the work of the Weather Bureau, we are certain that our readers will unreservedly admire the excellent chart that we present.

I have collected,[2] for teaching purposes, samples of a large number of meteorological charts published in Europe, and we must admit that the American publication far surpasses the similar ones that have been secured from other countries.

Undoubtedly the reader will ask for the cause of this inferiority. There are various reasons; I believe one of the most important is the scattering of our efforts. The practical Americans have concentrated the whole meteorological service of their vast territory at one single point and have thus been able to give the resulting total the scope that we see before us. In Europe, on the other hand, each country is confined to its own boundaries, be they broad or narrow, and gives only what these permit. *The total interest, energy, and initiative Europe thus expends, probably equals if it does not exceed that dedicated by our trans-Atlantic neighbors;* but our efforts lack coordination and, to use a business phrase, our enormous general expenses tie up a large portion of our capital.[3]

Because of its geographical location [on the western shores of the continent] all of western Europe is in a rather difficult position from the meteorological point of view. * * *

In short everything seems to argue in favor of the creation of a central meteorological service for Europe, well planned and well organized such as is that which exists for America. But alas, our ancient Europe, with its yet more ancient ideas, has difficulty in escaping from the grip of chauvinism. We allow ourselves to be stifled under the enormous expenses incurred by our military affairs * * * and we can not find on our old earth one voice carrying weight enough to stop these follies. We throw our millions into the gulf of an almost criminal insanity without being able to bring about that calm of which we have such need, and to which we all aspire. America, taking a broader view, has thus far relegated to the background that which we have placed first, and she can thus further the greater good of humanity by giving more liberally to science and to progress.

Let us thank her for this beautiful example that she sets us, and vow that some day Europe, wiser, shall do as well.

NORTHERN HEMISPHERE MAP INTERRUPTED.

The following announcement appears on the Weather Map of the Northern Hemisphere for August 6, 1914:

Owing to the state of war involving the great nations of Europe, the meteorological observations from regions in Europe and Asia heretofore employed by the Weather Bureau in the construction of its chart of the Northern Hemisphere are no longer received, and the issue of this map will be suspended from this date until such time as the reports can be resumed. The publication of the daily map of the United States will be continued as heretofore, and those recipients of the map of the Northern Hemisphere who make application therefor, including paid subscriptions, will be listed to receive the weather map of the United States. Unless application is received the map will not be sent, except to paid subscriptions.

C. F. MARVIN,
Chief of Bureau.

[1] **Vandevyver.** Les nouvelles cartes synoptiques du "Weather Bureau" de Washington. Ciel et terre, Bruxelles, 1914, juin, **35:** 169-172.

[2] Such a collection may be seen, displayed in frames in the library of the Washington office of the U. S. Weather Bureau.—[C. A., jr.]

[3] Italics are ours.—EDITOR.

SECTION III.—FORECASTS.

STORMS AND WARNINGS FOR JULY.

By EDWARD H. BOWIE, District Forecaster.

[Dated Washington, D. C., Aug. 12, 1914.]

NORTHERN HEMISPHERE PRESSURE.

Alaska.—Over the Aleutian Islands pressure averaged above normal while other Alaskan stations showed pressure averages decidedly below, particularly Valdez and Sitka. The first half of the month was characterized by generally low pressure. Lows occurred about the 1–2, 3–4, 8, 12, 14–15, 21–22, 24 and 30, and highs about the 5–6, 15–16, 18, and 26th. During the latter half of the month pressure at Dutch Harbor was continuously above normal, pressure reaching a maximum on the 19th and 24th of 30.42 inches.

Honolulu.—Pressure averaged slightly below normal. During the first half of the month pressure was slightly above the seasonal average with little fluctuation. During the latter half, however, pressure was below normal generally. Lows occurred on the 16, 20–22, 25–26, and 30–31. The principal high of the month occurred on the 10–11.

Iceland.—Pressure averaged slightly above normal, being almost continuously above from the 4 to 18 and from the 22 to the end of the month. Lows occurred on the 1, 3, 7–8, and 19–21; and highs on the 5, 9–16, 22–23, and 26–28.

Azores.—Changes over this region were not marked and pressure was generally above normal except from the 7 to 13 and on the last day of the month. The most important low of the month occurred from the 7 to 13, there being two centers apparently, one on the 8–9 and the other on the 10. The only other depression of any consequence occurred on the last day of the month. High crests occurred on the 5–6, 16–17, and 27th with several minor crests during the last half of the month.

Siberia.—Pressure oscillations were slight but of frequent occurrence. The most important storms being those of the 7th, 10–11, and 14–15. Pressure for the month as a whole averaged about normal.

Severe storms visited the Asiatic east coast about the 24th and again on the 27–29. Pressure was low over northern Japan on the 24th, a pressure of 29.29 inches (744 mm.) being reported at Nemuro on that date. The other storm referred to was probably of subtropical origin, being first indicated at Shanghai on the 27th with a pressure reading of 29.21 inches (742 mm.) and later at Vladivostock on the 29th with pressure reading 29.06 inches (738 mm.).

PRESSURE OVER THE UNITED STATES.

The month opened with an elongated area of high pressure extending from Maine southward to Bermuda and another over the western Plains States, a low of slight intensity being over the Upper Lakes attended by showers through the middle Mississippi Valley and Upper Lake Region.

The Lake Region disturbance moved eastward to the St. Lawrence Valley by the morning of the 2d with decreased intensity and a secondary disturbance was over Rhode Island, which during the next 24 hours passed to the ocean. In connection with these disturbances showers and thunderstorms occurred from the Mississippi Valley eastward.

The high area over the western Plains States moved southeastward to Missouri, thence northeastward to the Lower Lakes and thence southeastward to the Middle Atlantic coast. During the passage of this high across the Lower Lakes afternoon thunderstorms occurred quite generally throughout the middle and eastern Gulf States.

On the evening of the 4th the wind circulation over Georgia indicated the development of a disturbance over that region. On the morning of the 6th vessel reports indicated the presence of this disturbance off the south Atlantic coast 200 or 300 miles southeast of Cape Hatteras. By the morning of the 7th it was over Long Island with increased energy, high winds being reported at Nantucket and Block Island. It passed to the Grand Banks during the 48 hours following.

Another high area of very slight intensity followed much the same course as the preceding high. This high developed over the Rocky Mountain region during the 2d and 3d.

A low area that appeared over British Columbia on the evening of the 4th passed to Manitoba by the 6th and thence east-northeastward into Canada, little precipitation attending it.

An offshoot from the more or less permanent Pacific high area was central over northwestern Wyoming on the morning of the 6th and passed thence eastward across the Lake region during the next four days.

A disturbance that made its appearance over Alberta on the 9th moved east-southeastward and on the morning of the 11th was over North Dakota, thence moving eastward to Lake Michigan by the 13th and to the Ohio Valley by the 15th. During the next 24 hours it disappeared. It caused showers and thunderstorms over the northern Rocky Mountain region and Plains States and from the Mississippi Valley eastward except in the North Atlantic States.

The low which followed it was over Alberta on the morning of the 14th, and during the next two days passed to western Ontario and by the 19th was over the Canadian Maritime Provinces, having caused showers and thunderstorms from the Mississippi Valley eastward.

A high-pressure area that appeared on the north Pacific coast on the 15th, during the next two days threw off an offshoot which was central on the 17th over the western Plains States. It passed thence to the middle Mississippi Valley by the 19th and to the Atlantic seaboard by the evening of the 20th, a portion of it persisting over the South Atlantic States for the two days following.

On the evening of the 19th a low-pressure area made its appearance over Alberta and during the next 48 hours moved to Nebraska. It passed thence northeastward to

the Lake region, causing showers and thunderstorms over northern districts from the Plains States eastward.

From the 20th to the 25th pressure was high over the East Gulf and South Atlantic States.

An offshoot from the subpermanent Pacific high-pressure area was central on the morning of the 21st over the North Pacific States and by the following morning it had passed to the western Plains States. It passed thence to the Upper Lakes by the evening of the 23d, and was not thereafter traceable on the weather charts.

During the 23d and 24th conditions remained unsettled over a belt of territory extending from the Lake region to Oklahoma.

During the night of the 26th-27th a low developed over the Middle Atlantic States and on the morning of the 28th was near Norfolk, Va. In the 24 hours following it passed off the coast, and during the next several days proceeded slowly north-northeastward until at the end of the month it was southeast of Nantucket.

On the morning of the 27th pressure was above normal in the neighborhood of Hudson Bay and during the next 24 hours increased, a reading of 30.38 inches being reported at White River, Ontario. The high remained practically stationary over this region until the 29th, after which date it moved very slowly southeastward with decreasing intensity, giving record low temperatures for the month of July over portions of Virginia and temperatures decidedly below the seasonal average over the Atlantic States generally. Another high center had in the meantime appeared over the upper St. Lawrence Valley, which at the end of the month was over the ocean.

Conditions over the West during the last few days of the month were stagnant.

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, JULY, 1914.

By ALFRED J. HENRY, Professor of Meteorology, in charge of River and Flood Division.

[Dated Washington, D. C., Aug. 31, 1914.]

There were no floods of consequence in any part of the United States during the month. The Arkansas in eastern Colorado was at the flood stage several times during the last 10 days of the month, but beyond overflowing the bottom lands no damage was done.

The Mississippi in the Dubuque, Iowa, section was considerably higher than the ordinary July stages. Owing to the high water of the previous month no crops were raised on the lowlands along the river.

During the second week of the month the rivers of the Carolinas were at relatively high stages but flood stages were not reached.

MEAN LAKE LEVELS DURING JULY, 1914.

By UNITED STATES LAKE SURVEY.

[Dated Detroit, Mich., Aug. 4, 1914.]

The Notice to Mariners bearing the above date reports the following levels and changes in levels:

Data.	Lakes.			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during July, 1914:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.68	580.74	572.83	246.
Above or below—				72
Mean stage of June, 1914	+ 0.19	+ 0.14	− 0.21	− 0.
Mean stage of July, 1913	+ 0.04	+ 0.54	− 0.74	− 1.19
Average stage for July, last 10 years	+ 0.18	− 0.38	− 0.07	− 0.13
Highest recorded July stage	− 1.14	− 2.84	− 1.58	− 2.00
Lowest recorded July stage	+ 1.20	+ 0.84	− 1.37	+ 2.13
Probable change during August, 1914	+ 0.2	− 0.1	− 0.2	− 0.3

SECTION V.—BIBLIOGRAPHY.

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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C. FITZHUGH TALMAN, Professor in Charge of Library.

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SECTION VI.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF THE MONTH.

By P. C. DAY, Climatologist and Chief of Division.

[Dated Washington, Weather Bureau, Sept. 4, 1914.]

PRESSURE.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing directions of the winds, are graphically shown on chart VII, while the average values for the month at the several stations, with the departures from the normal, are shown in Tables I and III.

The mean barometric pressure for the month as a whole was above the normal, as in several preceding months, over much the greater portion of the country, only limited areas, comprising the Middle and South Atlantic States, the middle Mississippi Valley, and the extreme northern portion of the Rocky Mountain districts, showing values near to or slightly below the normal. The positive departures, while quite general, were as a rule moderate except that they were rather marked in restricted areas in the upper Lake region, the central and southern Rocky Mountain States, and southern California.

At the beginning of the month a moderate barometric depression moved eastward over the Lake region, and following in its wake was an extensive, though not marked, area of high pressure, which dominated the weather over eastern districts during the first few days and passed to sea about the 6th. From the 5th to the 8th a moderate disturbance passed northward along the Atlantic seaboard, with showery, unsettled weather in the Atlantic States. During the following week no pressure changes of consequence occurred, but the distribution had a tendency to relatively low readings to the northward, with southerly winds over eastern districts. From the 15th to the 18th a low moved eastward over the northern States, but thereafter relatively high pressure obtained over most of the country during the remainder of the month.

The distribution of the highs and lows was favorable for the frequent occurrence of southerly winds over the Rocky Mountain region and all districts to the eastward, while the prevailing directions were variable to the westward.

TEMPERATURE.

At the beginning of the month moderate temperatures obtained in nearly all portions of the country. By the 4th higher temperatures had overspread the Northwest and extended into the Plains region, and at the same time the weather had become unusually warm in the Southwest, but readings continued below the normal over the northern portion of eastern districts. By the 10th atmospheric pressure had decreased considerably in the Northwest and southerly winds and warmer weather had set in over the Plains States and Mississippi Valley, which gradually extended eastward and southward to the Atlantic and Gulf States. During the following week unusually warm weather prevailed over interior districts, the afternoon temperatures rising to 100°, or above, at many points in the Ohio Valley and to the westward.

About the 16th cooler weather set in over the Northwest, and during the following few days it advanced into the Missouri Valley and Plains region, greatly relieving the heated conditions that had prevailed in those sections. During the following few days the cool weather advanced eastward and southward, the temperature becoming quite low for the season of the year in the Ohio Valley and to the eastward. About the beginning of the third decade the distribution of atmospheric pressure was such as to again favor southerly winds and warm, humid weather over all interior portions of the country, and high temperatures obtained in the great central valleys and extended into eastern and southern districts. However, the last few days of the month brought much cooler weather to the northern States from the upper Mississippi Valley eastward.

For the month as a whole the temperature averaged above the normal in all districts east of the Rocky Mountains, save in the northeastern States, and also over the northern Mountain and Pacific Coast States. The greatest plus departures occurred in the Mississippi drainage area, where at some points the values were about 6° above the normal. The averages were less than the normal from the Middle Atlantic States northeastward and also from the central and southern Rocky Mountain region westward to the Pacific. However, the minus departures were not marked, reaching values as great as 3° only in limited areas in the northeast and in the central mountain districts of the West.

PRECIPITATION.

In the opening week of the month precipitation was unusually heavy over much of the Plains region, especially in western Texas and eastern New Mexico, the greater part of Kansas and portions of the adjoining States, while generous amounts were received over large portions of the Atlantic coast area, and the middle and east Gulf States, but over the Ohio and middle and upper Mississippi Valleys and the Lake region the rainfall was generally light. During the second week precipitation was local in character and the amounts were small, except over limited areas in the Atlantic and Gulf States and locally in the Plains States and upper Lake region, where in a few places they were in excess of 2 inches. Over much of the great cereal and grass producing States the rainfall was light, and none occurred in considerable portions of the Ohio Valley, the region of the Great Lakes, and over most of the Plains States.

About the middle of the month a disturbance moved eastward over the Lake region and was accompnaied by generous rains in much of the Ohio Valley, greatly relieving the severe drought that had persisted in that locality, and good showers also occurred at numerous points in other eastern districts, but severe drought continued in Missouri and portions of the adjoining States to the eastward and southward, and it was becoming severe in Texas. The last decade of the month was marked by deficient rainfall and more than the usual

amount of sunshine over the great agricultural districts. Generous local amounts were received in scattered localities, but over much of the central valleys and throughout the West there was little beneficial rain and drought had become severe in many localities.

For the month as a whole the precipitation was below the normal over much the greater part of the country. The amounts were above normal at many points in the more eastern States and also in the Plateau region, while in extreme western Texas and locally in the eastern portions of Colorado and New Mexico the falls were heavy, ranging from 2 to nearly 4 inches above the normal. However, in the great central valleys and the Plains region, including nearly the whole of Texas, precipitation was markedly deficient, the negative departures amounting to 2 inches, or more, over large areas.

For the season, March 1 to the end of July, the precipitation was below the normal over much of the central and southern portions of the country from the Rocky Mountains eastward. Numerous sections have received but little more than half the normal and some localities even less than that amount. In the Pacific Coast States, also, the rainfall was deficient.

GENERAL SUMMARY.

The marked features of the weather for July, 1914, were the deficient rainfall, unusually large percentage of sunshine, and persistence of high temperatures in the great corn-producing States and in the central and western portions of the cotton belt. This lack of sufficient rain in the corn belt, coming as a continuation of deficient moisture during the preceding month, and at a critical period in the development of the crop resulted in a marked deterioration in the condition of corn during the month. In the spring wheat belt the month also was hot and dry, resulting in considerable damage.

In the central and western portions of the cotton belt the rainfall was likewise deficient which, following more or less droughty conditions at the beginning, retarded the growth of plants and depreciated the general outlook. However, in the eastern portion of the belt the rainfall was more generous and vegetation made satisfactory progress.

Over the western Plains region and the Mountain and Plateau districts moisture was sufficient to maintain the ranges and cultivated crops in excellent condition, especially in the southern portion, and irrigation water continued plentiful. At the close of the month drought was becoming severe in the north Pacific Coast States.

Local, severe storms were quite frequent during the month, the most noteworthy of which were the destructive hailstorms that visited northwestern South Carolina on July 6 and 7. Great damage to growing crops, estimated at nearly a million dollars, was sustained in four counties in that locality. The area of destruction has been estimated at about 50,000 acres, on which the loss of crops ranged from 50 to 90 per cent.

Average accumulated departures for July, 1914.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	Inches	Inches	Inches			P. ct.	P. ct.
New England	66.0	−2.7	− 9.6	3.43	−0.20	−2.20	6.2	+1.1	81	+ 1
Middle Atlantic	73.0	−1.4	− 2.5	4.41	−0.10	−2.80	6.0	+1.1	76	+ 2
South Atlantic	79.1	+0.1	+ 3.0	4.56	−1.50	−9.40	5.1	−0.1	75	− 5
Florida Peninsula	81.7	−0.2	− 3.3	4.25	−2.20	−8.30	5.3	+0.3	75	− 3
East Gulf	81.3	+1.0	+ 3.0	4.86	−0.50	−6.60	5.6	+0.2	76	− 2
West Gulf	84.0	+2.1	+ 4.3	1.80	−1.40	−6.80	4.1	0.0	68	− 6
Ohio Valley and Tennessee	78.0	+1.2	+ 2.0	3.02	−1.00	−7.40	4.5	−0.1	62	− 7
Lower Lakes	71.2	−0.5	− 6.7	1.53	−1.90	−1.50	4.5	0.0	69	0
Upper Lakes	69.2	+1.2	+ 2.5	2.56	−0.60	+0.30	4.2	−0.4	74	+ 2
North Dakota	72.8	+3.8	+14.4	2.41	−0.50	+2.40	3.0	−1.4	68	+ 2
Upper Mississippi Valley	78.3	+2.9	+12.4	1.33	−2.30	−5.60	4.1	−0.2	63	− 5
Missouri Valley	78.7	+2.9	+17.2	2.20	−1.60	−2.40	3.9	−0.3	62	− 4
Northern slope	70.5	+2.4	+16.1	0.78	−0.80	−1.90	3.9	+0.2	53	+ 1
Middle slope	79.1	+2.3	+15.8	1.52	−1.40	−3.40	4.5	+0.4	60	0
Southern slope	80.8	+0.4	+ 6.5	3.06	+0.20	+0.60	3.3	−1.2	60	+ 1
Southern Plateau	77.1	−1.9	+ 1.9	1.85	−0.60	−0.40	4.3	+1.0	50	+12
Middle Plateau	71.4	−0.7	+ 8.4	1.05	−0.40	+0.40	4.4	+1.3	46	+14
Northern Plateau	73.7	+2.8	+17.3	0.89	+0.40	−0.50	3.3	+0.6	42	+ 1
North Pacific	61.5	−0.3	+13.4	0.07	−0.70	+0.30	3.6	−1.0	72	+ 7
Middle Pacific	64.2	−1.3	+ 6.7	0.00	0.00	−0.40	4.0	+0.5	64	− 2
South Pacific	69.3	−0.6	+13.7	0.00	0.00	+3.80	3.2	+0.4	68	+ 4

Maximum wind velocities, July, 1914.

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
		mi./hr.				mi./hr.	
Augusta, Ga.	26	50	n.	New York, N. Y.	23	88	nw.
Block Island, R. I.	6	56	ne.	Norfolk, Va.	13	54	nw.
Columbia, S. C.	9	59	sw.	Do.	15	58	w.
Fort Wayne, Ind.	24	52	nw.	Pittsburgh, Pa.	12	54	nw.
Fort Worth, Tex.	24	50	e.	Topeka, Kans.	16	50	nw.
Louisville, Ky.	10	52	se.	Trenton, N. J.	27	72	ne.
Mt. Tamalpais, Cal.	7	50	nw.				

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data, as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Summary of temperature and precipitation, by sections, July, 1914.

Section.	Temperature (°F.).								Precipitation (in inches and hundredths).					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
Alabama	81.6	+1.5	Newbern	107	26	2 stations	56	8	4.23	−1.03	Mentone	9.06	Fort Deposit	0.86
Arizona	78.7	−1.3	Mohawk	117	27†	Fort Valley	39	22	3.10	+0.86	Willow, Wash	8.59	Yuma	T.
Arkansas	82.6	+2.8	5 stations	107	14†	2 stations	54	31	2.69	−1.05	Bentonville	7.51	Corning	0.32
California	72.4	−1.6	Greenland Ranch	122	8	Greenville	28	9	0.06	+0.02	Nellie	3.75	70 stations	0.00
Colorado	66.1	−0.2	2 stations	102	12†	Dillon	29	1†	3.50	+1.15	Victor	11.23	Palisades	T.
Florida	81.6	+0.5	Federal Point	102	25†	Jasper	58	31	5.97	−1.77	Homestead	13.51	Malabar	1.87
Georgia	80.8	+0.7	Waynesboro	108	26	Blue Ridge	50	31	4.74	−0.78	Marshallville	8.53	Savannah	1.85
Hawaii (June)	71.2	......	Makaweli	92	14	Volcano House	51	18	8.23	......	Hakalau	43.35	2 stations	0.00
Idaho	69.7	+1.4	Culdesac	111	11	New Meadows	25	21	0.87	+0.24	Blackfoot	2.80	Murtaugh	T.
Illinois	79.0	+3.1	Greenville	109	16	Morris	42	3	1.50	−2.06	Olney	3.63	Metropolis	0.05
Indiana	77.6	+2.2	Shoals	112	12	Salamonia	43	30	1.85	−1.82	Forest Reserve	5.82	Notre Dame	0.20
Iowa	76.6	+2.5	Centerville	109	12	2 stations	43	3†	2.27	−1.69	Oskaloosa	6.50	Davenport	0.44
Kansas	79.9	+2.4	Minneapolis	111	15	Blakeman	45	1	2.69	−1.06	Madison	7.14	Dodge City	0.36
Kentucky	78.8	+2.0	Greensburg	109	12	Willliamstown	43	30	3.20	−1.15	Berea	7.90	Paducah	T.
Louisiana	83.0	+1.2	2 stations	106	1†	Antioch	57	31	7.07	+0.42	Cades	18.66	Logansport	0.60
Maryland & Delaware	74.4	−1.2	....do	101	23†	Deer Park	35	30†	3.10	−1.01	Delaware City	7.38	Woodstock	1.28
Michigan	69.8	−1.2	Adrian	103	22	Seney	33	19	2.64	−0.15	Iron Mountain	9.42	Bloomingdale	0.27
Minnesota	72.4	+3.5	Moose Lake	101	26	2 stations	36	18	2.48	−1.30	New London	5.73	Moose Lake	0.62
Mississippi	82.2	+1.5	3 stations	105	1†	Duck Hill	55	31	3.76	−1.27	Pearlington	7.68	Hernando	0.62
Missouri	80.5	+3.7	Grant City	109	12	Ironton	45	30	2.67	−1.66	Warsaw	7.61	Cardwell	0.34
Montana	68.7	+3.2	Fallon	107	20	Pleasant Valley	23	22	0.80	−0.57	Fallon	3.48	Hamilton	0.00
Nebraska	76.6	+2.1	Ewing	111	26	Hillside	37	1	1.84	−1.63	Orleans	5.04	Arcadia	0.37
Nevada	72.4	−0.6	Leeland	118	17	Tecoma	32	23	0.52	+0.14	Sharp	1.70	2 stations	0.00
New England	66.4	−2.7	Cavendish, Vt	93	18	Bloomfield, Vt	35	26	3.59	−0.23	Bridgeport, Conn	7.10	Fairfield, Me	0.93
New Jersey	71.5	−2.3	Bridgeton	97	23	Charlotteburg	40	20	6.05	+1.17	Haddonfield	8.57	Cape May	1.94
New Mexico	70.1	−1.9	2 stations	102	16†	Harvey's Upper Ranch.	37	18	4.83	+2.38	Gallinas P. sta	12.02	Lanark	1.27
New York	68.2	−1.4	Otto	98	16†	Lake Placid	31	20	3.25	−0.85	Sharon Springs	9.55	Fredonia	0.56
North Carolina	76.7	−0.2	2 stations	106	25†	Banners Elk	41	31	4.71	−0.95	Rock House	9.56	Elizabethtown	0.70
North Dakota	72.1	+4.5	Napoleon	109	26	2 stations	36	9†	2.31	−0.36	Dickinson	5.50	Beach	0.41
Ohio	74.0	+0.5	Hamilton	106	12	....do	41	30†	2.19	−1.80	Cambridge	8.36	2 stations	0.72
Oklahoma	84.6	+4.6	Chattanooga	113	31	Hurley	50	1	1.63	−1.73	Hurley	5.50	....do	T.
Oregon	67.4	+1.7	Umatilla	110	18	Whitaker	17	21	0.29	−0.23	Headworks (2)	2.35	Deadwood	0.00
Pennsylvania	71.3	−0.9	Punxsutawney	101	24	West Bingham	38	31	4.19	−0.30	Coatesville	10.29	Ridgway	1.10
Porto Rico	78.3	−0.5	Jayuya	97	3†	Aibonito	52	12	4.48	−1.84	Rio Grande	20.84	Santa Isabel	0.77
South Carolina	80.0	+0.1	2 stations	107	25	Conway	53	22	5.16	−0.40	Rimini	9.90	Dillon	0.78
South Dakota	75.9	+4.1	Oelrichs	110	26	2 stations	39	17	2.13	−0.84	Fairfax	6.45	Hot Springs	0.43
Tennessee	79.4	+2.0	Wildersville	110	12	Erasmus	42	31	4.34	−0.45	Erasmus	8.95	Brownsville	0.29
Texas	84.4	+2.1	7 stations	110	19†	Mount Blanco	54	25	1.51	−1.57	Andrews	11.90	13 stations	0.00
Utah	70.1	−2.0	Lemay	110	27	Scofield	31	4	1.81	+1.27	Parowan	5.19	Low	0.00
Virginia	74.3	−0.9	Charlottesville	102	25	Burkes Garden	36	30†	4.27	−0.38	Blacksburg	9.60	Winchester	0.81
Washington	67.5	+1.3	Eltopia	111	18	2 stations	30	20	0.35	−0.47	Pomeroy	1.80	9 stations	0.00
West Virginia	73.1	−0.1	Point Pleasant	106	12	Bayard	38	31	4.11	−0.71	Elkins	7.74	Beckley	0.98
Wisconsin	71.6	+2.4	Grantsburg (2)	100	11†	Long Lake	38	29	3.29	−0.88	Florence	7.06	Neillsville	0.85
Wyoming	65.5	+1.6	Hyattsville	103	9	Norris, Y. N. P	26	23	1.14	−0.23	Knowles	4.38	3 stations	0.00

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m., seventy-fifth meridian time daily, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)...	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.80

In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred, the greatest precipitation of any single storm has been given, also the greatest hourly fall during that storm.

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values, except in the case of snowfall.

Chart I.—Hydrographs for several of the principal rivers of the United States.

Chart II.—Tracks of centers of high areas; and

Chart III.—Tracks of centers of low areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., seventy-fifth meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading and (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea level and standard gravity.

Chart IV.—Total precipitation. The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading, and

over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart V.—Percentage of clear sky between sunrise and sunset. The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VI.—Isobars and isotherms at sea level and prevailing wind directions. The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observations, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sea-level plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction $t_0 - t$, or temperature on the sea-level plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sea-level temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations; a few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VII.—Total snowfall. This is based on the reports from regular and cooperative observers and shows the depth in inches and tenths of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given.

Chart VIII.—Depth of snow on ground at end of the month, expressed in inches and tenths.

Charts VII and VIII are published only when the general snow cover is sufficiently extensive to justify their preparation.

TABLE I.—*Climatological data for United States Weather Bureau stations, July, 1914.*

Districts and stations.	Elevation of instruments.			Pressure in inches.			Temperature of the air, in degrees Fahrenheit.									Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation, inches.			Wind.								Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level, feet.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 or more.	Total movement, miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.			
New England.							**66.0**	**− 2.7**										**81**	**3.43**	**− 0.2**										**6.2**		
Eastport	76	67	85	29.88	29.96	+ .03	60.1	+ 0.3	83	14	69	47	2	52	30	55	52	78	1.21	− 2.2	8	5,648	s.	28	e.	7	7	14	10	6.2	....	....
Greenville	1,070	6	....	28.83	29.98	....	63.4	....	88	15	74	41	22	52	39	....	....	....	2.62	....	11	....	....	....	....	....	....	....	....	....	....	....
Portland, Me	103	82	117	29.88	30.00	+ .05	64.6	− 3.4	90	18	73	48	2	57	26	59	55	74	3.10	− 0.2	10	5,950	sw.	29	nw.	21	12	8	11	5.7	....	....
Concord	288	70	79	29.68	29.98	+ .02	66.8	− 2.3	89	17	77	46	4	57	33	....	....	....	3.49	− 0.3	11	3,410	se.	34	nw.	21	8	12	11	5.9	....	....
Burlington	404	11	48	29.55	29.98	+ .04	66.6	− 1.6	88	17	76	44	20	57	32	....	....	....	1.94	− 1.8	13	5,419	s.	25	sw.	17	4	18	9	5.9	....	....
Northfield	876	12	60	29.06	30.00	+ .06	63.3	− 3.3	85	17	75	39	22	52	36	60	58	84	4.22	+ 0.5	14	4,081	s.	41	s.	17	4	14	13	6.4	....	....
Boston	125	115	188	29.85	29.98	+ .02	68.6	− 2.7	90	18	76	51	3	61	24	63	60	78	2.64	− 0.7	10	6,435	sw.	34	nw.	21	8	13	10	5.6	....	....
Nantucket	12	14	90	29.97	29.98	.00	64.6	− 2.9	81	26	70	51	4	59	18	61	60	91	3.25	+ 0.6	11	10,854	sw.	47	ne.	6	9	13	9	5.8	....	....
Block Island	26	11	46	29.95	29.98	+ .01	65.2	− 2.9	82	18	71	53	4	60	17	62	61	89	4.27	+ 1.0	14	10,076	sw.	56	ne.	6	5	14	12	6.3	....	....
Narragansett Pier	....	9	....	....	....	....	66.0	− 3.9	87	18	73	50	4	59	20	....	....	....	4.94	....	12	....	s.	....	....	....	13	7	11	....	....	....
Providence	160	215	251	29.82	29.99	+ .02	68.0	− 5.4	87	18	76	51	3	60	24	62	58	76	2.81	− 0.7	11	7,875	sw.	48	nw.	21	5	14	12	6.6	....	....
Hartford	159	122	140	29.81	29.97	.00	69.4	− 2.2	89	13	78	54	20	61	26	63	60	77	4.30	+ 0.2	14	4,785	s.	26	ne.	6	5	6	20	7.1	....	....
New Haven	106	117	155	29.87	29.98	+ .01	69.4	− 2.5	89	18	77	54	1	62	23	63	60	78	6.51	+ 1.7	13	5,793	s.	39	n.	6	3	12	16	6.8	....	....
Middle Atlantic States.							**73.0**	**− 1.4**										**76**	**4.41**	**− 0.1**										**6.0**		
Albany	97	102	115	29.87	29.97	+ .01	71.0	− 1.0	90	17	80	51	1	62	28	63	59	70	2.25	− 1.6	12	4,679	s.	25	nw.	21	9	13	9	5.2	....	....
Binghamton	871	10	69	29.07	29.98	+ .01	69.4	− 0.5	89	9	79	48	1	60	30	....	....	....	3.98	+ 0.4	17	2,898	e.	24	n.	21	4	14	13	6.4	....	....
New York	314	414	454	29.65	29.98	.00	71.1	− 2.4	90	23	78	54	7	64	24	63	60	73	5.13	+ 0.6	15	9,107	s.	88	nw.	23	5	7	19	7.3	....	....
Harrisburg	374	94	104	29.60	29.99	+ .01	73.8	− 0.7	94	23	82	55	31	65	27	66	62	72	6.21	+ 2.3	13	4,146	e.	33	ne.	10	6	14	11	5.9	....	....
Philadelphia	117	123	190	29.87	29.99	+ .01	74.0	− 1.8	96	23	81	58	31	67	27	67	64	75	7.75	+ 3.4	13	5,974	sw.	36	ne.	29	6	9	16	6.5	....	....
Reading	325	81	98	29.64	29.98	....	73.3	....	95	23	82	54	30	65	30	66	62	74	4.21	0.0	17	4,058	se.	32	ne.	27	4	8	19	7.1	....	....
Scranton	805	111	119	29.15	30.00	+ .02	70.4	− 1.4	89	17	80	49	20	61	31	66	64	84	6.71	+ 2.9	16	3,842	n.	36	sw.	27	3	18	10	6.2	....	....
Atlantic City	52	37	48	29.94	29.99	+ .01	70.6	− 1.9	88	18	75	58	31	66	17	66	64	82	6.82	+ 3.0	16	5,282	sw.	27	s.	1	4	10	17	7.2	....	....
Cape May	18	13	49	29.99	30.01	+ .03	71.6	− 1.8	93	18	78	56	30	66	20	67	65	84	1.94	− 1.8	15	5,107	s.	21	nw.	19	5	18	8	5.7	....	....
Trenton	190	159	183	29.77	29.97	....	72.0	....	93	23	80	56	30	64	28	65	63	78	4.75	0.0	16	6,629	ne.	72	ne.	27	6	8	17	7.1	....	....
Baltimore	123	100	113	29.86	29.98	.00	76.3	− 1.0	99	23	84	57	31	68	27	68	63	67	2.55	− 2.3	11	4,799	s.	24	n.	11	6	17	8	5.7	....	....
Washington	112	62	85	29.86	29.98	− .02	75.9	− 0.9	98	23	85	56	30	67	27	68	65	73	2.32	− 2.3	12	3,877	s.	32	nw.	28	7	12	12	5.9	....	....
Lynchburg	681	153	188	29.26	29.99	− .02	76.0	− 1.3	98	12	87	50	31	65	31	68	65	74	4.53	+ 0.5	13	4,086	w.	40	nw.	1	13	13	5	5.1	....	....
Mount Weather	1,725	10	75	28.21	29.97	− .02	70.2	− 1.2	90	23	78	50	30	63	22	64	60	77	4.31	− 0.4	12	8,712	nw.	40	nw.	28	6	12	13	6.5	....	....
Norfolk	91	170	205	29.91	30.00	.00	76.7	− 1.7	93	24	84	59	30	69	23	71	68	79	3.91	− 1.9	17	7,911	sw.	58	w.	15	6	17	8	5.7	....	....
Richmond	144	11	52	29.85	30.00	− .01	76.9	− 2.3	98	25	87	57	31	67	29	69	65	74	3.00	− 1.4	13	4,854	s.	27	e.	11	9	18	4	4.8	....	....
Wytheville	2,293	40	47	27.70	30.00	.00	72.0	− 0.6	92	12	84	43	31	60	34	65	63	81	4.65	+ 0.2	11	2,999	w.	27	sw.	9	15	14	2	3.2	....	....
South Atlantic States.							**79.1**	**+ 0.1**										**75**	**4.56**	**− 1.5**										**5.1**		
Asheville	2,255	70	84	27.75	30.03	+ .01	72.3	+ 0.6	90	13	83	53	31	61	31	64	61	77	3.31	− 1.6	11	3,997	nw.	35	s.	13	11	15	5	4.5	....	....
Charlotte	773	68	76	29.20	30.02	.00	78.4	− 0.3	100	26	88	56	31	68	28	69	65	70	4.83	− 0.7	14	4,054	sw.	35	w.	14	8	18	5	5.1	....	....
Hatteras	11	12	50	29.99	30.00	− .01	77.6	− 1.0	92	25	83	65	7	72	18	73	71	82	2.88	− 3.2	11	9,229	sw.	40	nw.	13	17	10	4	4.0	....	....
Manteo	12	12	46	....	....	....	77.8	....	96	28	87	55	21	69	....	....	....	....	2.82	....	8	....	sw.	....	....	....	16	10	5	....	....	....
Raleigh	376	103	110	29.60	29.99	− .03	78.4	− 0.1	100	26	88	55	31	68	28	69	65	70	7.29	+ 1.2	10	4,910	ne.	37	nw.	14	13	14	4	4.3	....	....
Wilmington	78	81	91	29.93	30.01	.00	79.4	+ 0.7	99	25	88	60	31	71	27	72	70	78	2.38	− 4.6	7	5,552	sw.	28	sw.	16	9	21	1	4.6	....	....
Charleston	48	11	92	29.97	30.02	− .01	81.0	− 0.3	96	25	88	69	30	74	19	73	70	74	7.14	− 0.1	9	7,102	sw.	38	s.	3	11	14	6	4.8	....	....
Columbia, S. C	351	41	57	29.64	30.01	− .01	80.2	− 0.9	102	26	90	61	31	70	30	71	68	74	4.41	− 1.6	13	4,512	s.	59	sw.	9	12	17	2	4.4	....	....
Augusta	180	89	97	29.82	30.01	− .01	80.8	+ 0.3	102	26	91	64	31	71	32	71	68	73	6.39	+ 1.1	15	3,982	se.	50	n.	26	3	18	10	6.0	....	....
Savannah	65	150	194	29.96	30.03	.00	81.0	+ 0.5	100	25	90	69	10	72	26	73	71	78	1.85	− 4.3	12	7,330	sw.	38	s.	26	3	20	8	5.9	....	....
Jacksonville	43	96	129	29.99	30.04	+ .01	82.0	+ 1.1	99	25	90	69	31	74	24	74	71	78	5.13	− 1.1	12	6,276	sw.	32	w.	26	0	18	13	7.1	....	....
Florida Peninsula.							**81.7**	**− 0.2**										**75**	**4.24**	**− 2.2**										**5.3**		
Key West	22	10	64	30.01	30.03	.00	83.6	− 0.1	91	21	89	74	25	78	15	76	73	71	1.99	− 1.6	12	5,159	se.	31	sw.	8	15	13	3	4.4	....	....
Miami	25	37	72	30.03	30.06	....	81.2	− 0.7	92	5	88	70	31	74	19	75	73	76	4.52	− 2.7	15	4,321	se.	27	w.	30	3	13	15	7.2	....	....
Sand Key	23	39	72	29.99	30.02	− .01	83.0	....	90	17	86	72	6	80	13	77	74	75	2.56	....	6	6,350	se.	37	sw.	8	15	13	3	4.0	....	....
Tampa	35	79	96	30.01	30.04	.00	81.0	+ 1.0	92	13	89	68	10	73	21	75	72	77	6.21	− 2.2	16	4,086	ne.	28	ne.	14	3	22	6	6.6	....	....
Titusville	44	6	....	....	....	....	80.9	− 1.2	100	15	91	65	12	71	28	....	....	....	3.03	....	9	....	....	....	....	....	11	17	2	4.5	....	....
East Gulf States.							**81.3**	**+ 1.0**										**76**	**4.86**	**− 0.5**										**5.6**	....	....
Atlanta	1,174	190	216	28.83	30.04	+ .02	79.1	+ 1.5	95	12	88	64	8	70	28	70	67	72	3.66	− 1.1	13	6,136	w.	48	nw.	28	9	12	10	5.6	....	....
Macon	370	78	87	29.62	30.01	− .01	81.0	+ 1.3	99	25	91	65	23	71	28	72	69	72	5.68	+ 1.0	10	3,868	s.	36	n.	3	8	17	6	5.3	....	....
Thomasville	273	8	57	29.74	30.03	.00	81.8	0.0	100	26	92	65	31	71	26	73	72	82	6.20	+ 0.9	14	3,348	sw.	23	sw.	27	7	17	7	5.7	....	....
Pensacola	56	140	182	29.97	30.03	+ .02	81.6	+ 0.2	95	5	87	69	23	76	21	75	74	80	2.82	− 4.4	12	8,519	sw.	42	ne.	28	4	13	14	6.8	....	....
Anniston	741	9	57	29.26	30.04	+ .02	79.6	+ 1.7	96	1	91	60	30	68	31	....	....	....	5.37	+ 0.6	11	3,178	se.	40	nw.	17	12	13	6	4.8	....	....
Birmingham	700	11	48	29.28	30.03	+ .02	80.8	− 0.7	95	1	91	64	30	70	30	70	67	70	3.91	− 0.8	9	4,032	s.	39	nw.	2	10	17	4	4.8	....	....
Mobile	57	125	161	29.96	30.02	+ .01	81.8	+ 1.3	97	6	90	69	15	74	25	75	73	78	5.17	− 1.9	11	6,127	sw.	38	n.	27	4	23	4	5.6	....	....
Montgomery	223	100	112	29.78	30.02	.00	82.6	+ 1.6	98	26	92	69	7	73	26	72	68	69	2.26	− 2.4	9	4,172	sw.	27	nw.	27	10	17	4	4.6	....	....
Meridian	375	85	93	29.62	30.00	− .02	81.2	+ 1.2	98	7	91	64	31	71	30	72	69	74	4.34	− 0.2	13	3,397	sw.	32	w.	3	3	11	17	7.2	....	....
Vicksburg	247	62	74	29.75	30.02	+ .02	81.8	+ 1.4	95	3	90	69	10	73	23	74	72	79	4.88	+ 0.5	12	4,112	sw.	30	w.	2	9	13	9	5.2	....	....
New Orleans	51	90	121	29.96	30.01	+ .01	82.6	+ 1.3	96	1	90	70	18	75	22	76	74	82	9.18	+ 2.7	19	5,293	sw.	39	n.	18	4	19	8	6.2	....	....
West Gulf States.							**84.0**	**+ 2.1**										**68**	**1.80**	**− 1.4**										**4.1**		
Shreveport	249	77	93	29.73	29.99	+ .01	85.5	+ 3.4	103	14	96	70	23	75	27	74	70	67	0.84	− 2.9	7	4,520	se.	24	se.	22	16	13	2	3.9	....	....
Bentonville	1,303	11	44	28.66	29.99	+ .02	78.6	+ 0.1	98	15	88	60	19	70	25	....	....	....	7.51	+ 3.2	9	1,704	se.	14	n.	7	17	9	5	4.1	....	....
Fort Smith	457	79	94	29.49	29.96	− .01	83.9	+ 2.9	105	15	94	65	31	74	28	72	67	63	2.65	− 1.2	10	4,620	e.	39	s.	4	11	13	7	5.3	....	....
Little Rock	357	139	147	29.62	29.98	− .01	82.7	+ 2.1	101	14	92	67	31	74	24	72	68	67	3.71	− 0.3	11	4,940	sw.	42	n.	4	2	24	5	5.8	....	....
Brownsville	57	3	40	....	....	....	85.0	....	98	19	94	72	13	76	23	....	....	....	T.	....	0	....	....	....	....	....	....	....	....	....	....	....
Corpus Christi	20	69	77	29.98	30.00	+ .04	82.8	+ 0.1	95	19	88	72	12	77	19	77	76	83	0.91	− 0.8	2	10,927	se.	42	se.	16	17	14	0	3.7	....	....
Dallas	512	109	117	29.44	29.97	....	87.4	....	102	30	98	71	24	77	25	....	....	....	1.00	....	3	5,985	se.	31	sw.	25	12	18	1	4.1	....	....
Fort Worth	670	106	114	29.24	29.93	− .03	86.6	+ 2.9	106	31	98	69	24	75	30	72	65	54	0.73	− 2.3	2	6,555	s.	50	e.	24	12	17	2	4.1	....	....
Galveston	54	106	114	29.97	30.03	+ .05	83.0	0.0	94	7	88	74	11	79	18	77	75	82	1.29	− 2.7	6	6,470	s.	35	se.	9	15	12	4	4.0	....	....
Houston	138	111	121	29.87	30.01	....	84.8	+ 1.8	102	30	94	70	22	75	27	....	....	....	1.77	....	5	5,006	s.	33	e.	22	12	15	4	4.8	....	....
Palestine	510	64	72	29.45	29.97	....	85.3	+ 3.8	100	7	96	70	25	75	25	74	69	65	0.17	− 2.8	1	4,737	sw.	21	se.	22	22	9	0	3.2	....	....
San Antonio	701	80	91	29.26	29.97	+ .02	85.6	+ 3.2	102	8	97	71	20	74	28	73	67	63	0.02	− 2.2	2	5,952	s.	30	se.	9	18	13	0	3.1	....	....
Taylor	**582**	**55**	**63**	**29.41**	**30.02**	**+ .00**	**85.0**	**+ 2.3**	**101**	**7**	**96**	**72**	**4**	**74**	**28**	....	....	....	**0.21**	**− 2.4**	**1**	**6,470**	**s.**	**27**	**se.**	**12**	**17**	**14**	**0**	**3.6**	....	....

TABLE I.—*Climatological data for United States Weather Bureau stations, July, 1914*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level, feet.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure in inches: Station, reduced to mean of 24 hours.	Pressure in inches: Sea level, reduced to mean of 24 hours.	Pressure in inches: Departure from normal.	Temperature of the air, in degrees Fahrenheit: Mean max.+mean min.÷2.	Temperature: Departure from normal.	Temperature: Maximum.	Temperature: Date.	Temperature: Mean maximum.	Temperature: Minimum.	Temperature: Date.	Temperature: Mean minimum.	Temperature: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation, inches: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 or more.	Wind: Total movement, miles.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
Ohio Valley and Tennessee.							**78.0**	**+ 1.2**										**62**	**3.02**	**− 1.0**										**4.5**		
Chattanooga	762	189	213	29.24	30.03	+ .01	79.6	+ 1.8	97	11	90	62	31	69	30	69	64	66	6.91	+ 3.0	9	5,238	ne.	47	nw.	14	12	12	7	4.9	.....	....
Knoxville	996	93	100	28.99	30.02	.00	77.4	+ 1.2	98	12	88	59	31	66	29	68	64	68	7.11	+ 2.9	11	3,230	sw.	37	nw.	14	12	6	13	5.5	.....	....
Memphis	399	76	97	29.60	30.02	+ .02	83.2	+ 2.5	98	11	92	66	30	74	28	73	68	66	0.58	− 2.9	7	5,401	sw.	40	sw.	15	11	12	8	5.0	.....	....
Nashville	546	168	191	29.44	30.01	.00	81.4	+ 2.0	102	12	92	61	31	71	32	68	62	59	2.58	− 1.8	10	5,670	se.	48	nw.	1	13	11	7	4.3	.....	....
Lexington	989	75	102	28.96	30.00	− .01	77.6	+ 1.0	100	12	88	57	19	67	29	....	....	....	2.63	− 1.8	8	5,797	s.	34	nw.	26	14	10	7	3.9	.....	....
Louisville	525	219	255	29.44	30.01	+ .01	80.4	+ 1.8	102	12	91	58	19	70	32	67	60	55	2.59	− 1.2	7	6,674	n.	52	se.	10	16	9	6	3.8	.....	....
Evansville	431	72	82	29.53	29.99	− .01	82.2	+ 2.9	102	12	93	60	19	72	28	68	61	55	1.41	− 2.4	4	3,989	ne.	39	n.	17	17	9	5	3.8	.....	....
Indianapolis	822	154	164	29.13	30.00	+ .01	78.5	+ 2.3	100	12	90	55	19	68	29	65	58	54	0.49	− 3.6	4	4,774	sw.	31	sw.	13	11	18	2	4.3	.....	....
Terra Haute	575	96	129	29.38	29.98	......	80.0	......	101	12	92	57	19	68	33	66	59	53	1.12	......	7	5,106	sw.	45	e.	16	11	18	2	4.6	.....	....
Cincinnati	628	152	160	29.33	30.00	.00	79.2	+ 1.5	103	12	90	58	19	69	32	67	61	59	3.00	− 0.5	8	4,063	n.	37	sw.	16	10	17	4	4.9	.....	....
Columbus	824	173	222	29.14	29.99	− .01	75.9	+ 0.6	100	12	87	53	19	65	31	66	61	63	1.64	− 2.0	7	6,137	nw.	40	nw.	13	19	6	6	3.6	.....	....
Dayton	899	181	216	29.05	29.97	......	76.4	+ 0.2	101	12	88	53	19	65	31	66	60	63	1.72	− 1.6	6	5,663	n.	47	nw.	13	15	11	5	3.9	.....	....
Pittsburgh	842	353	410	29.10	29.99	− .01	74.0	− 0.6	94	12	84	55	31	64	29	65	60	64	1.89	− 2.5	9	5,954	nw.	54	nw.	12	10	14	7	4.7	.....	....
Elkins	1,940	41	50	28.02	30.01	.00	69.8	− 0.7	92	12	82	43	31	57	35	62	60	79	7.74	+ 3.1	10	2,189	w.	26	nw.	24	9	13	9	5.6	.....	....
Parkersburg	638	77	84	29.36	30.01	.00	76.0	+ 0.5	100	12	87	53	31	65	37	66	61	64	2.13	− 2.5	5	3,529	n.	27	nw.	13	16	12	3	4.2	.....	....
Lower Lake Region.							**71.2**	**− 0.5**										**69**	**1.53**	**− 1.9**										**4.5**		
Buffalo	767	247	280	29.17	29.98	+ .01	70.0	− 0.2	86	9	77	51	19	63	26	64	61	74	1.30	− 2.1	11	8,598	sw.	42	sw.	21	6	18	7	5.5	.....	....
Canton	448	10	61	29.51	29.98	......	66.6	− 3.9	90	15	78	39	22	55	39	....	....	....	2.38	− 0.8	11	5,255	ne.	31	sw.	17	18	10	3	3.2	.....	....
Oswego	335	76	91	29.61	29.98	+ .02	68.0	− 1.6	88	17	75	53	1	61	22	62	59	71	1.15	− 2.1	7	5,053	w.	27	ne.	28	16	4	11	4.8	.....	....
Rochester	523	97	113	29.44	30.00	+ .03	71.1	+ 0.7	90	11	80	54	20	63	25	62	57	64	0.91	− 2.2	8	4,775	ne.	30	nw.	21	15	7	9	4.8	.....	....
Syracuse	597	97	113	29.36	30.00	+ .03	69.8	− 1.0	88	9	78	53	22	61	28	63	59	72	2.64	− 1.0	12	5,642	s.	38	nw.	17	8	17	6	5.3	.....	....
Erie	714	92	102	29.24	29.99	+ .01	70.8	− 1.0	86	23	78	56	31	64	20	64	60	69	1.33	− 1.9	6	5,663	w.	28	n.	12	7	18	6	5.2	.....	....
Cleveland	762	190	201	29.19	30.00	+ .01	71.8	− 0.7	90	22	78	56	31	65	25	65	61	69	1.00	− 2.6	8	7,239	se.	33	nw.	23	11	15	5	4.4	.....	....
Sandusky	629	62	103	29.32	29.99	.00	73.6	0.0	93	22	81	58	4	66	25	66	61	67	1.55	− 2.2	6	6,500	ne.	33	n.	28	9	16	6	4.6	.....	....
Toledo	628	208	246	29.33	30.00	+ .01	74.3	+ 0.6	97	22	84	52	19	65	28	65	61	65	1.25	− 2.0	5	7,759	n.	37	nw.	23	17	10	4	3.4	.....	....
Fort Wayne	856	113	124	29.09	30.00	......	75.0	+ 1.5	97	12	86	51	19	64	32	67	63	68	3.17	......	6	4,626	ne.	52	nw.	24	16	11	4	4.0	.....	....
Detroit	730	218	245	29.23	30.00	+ .02	72.6	+ 0.6	93	11	82	53	29	63	27	64	59	67	1.80	− 1.7	5	6,473	e.	34	ne.	28	12	14	5	4.8	.....	....
Upper Lake Region.							**69.2**	**+ 1.2**										**74**	**2.56**	**− 0.6**										**4.2**		
Alpena	609	13	92	29.36	30.02	+ .05	66.1	+ 0.3	88	25	75	45	19	57	37	62	58	77	1.01	− 2.0	9	6,487	se.	31	se.	3	9	19	3	4.5	.....	....
Escanaba	612	54	60	29.35	30.00	+ .03	67.4	+ 0.9	87	16	75	49	2	60	23	63	60	79	5.96	+ 2.6	12	5,912	s.	31	ne.	27	14	10	7	4.4	.....	....
Grand Haven	632	54	92	29.32	29.99	+ .01	70.2	+ 0.5	90	22	78	52	29	62	24	64	60	71	1.32	− 1.3	7	5,428	w.	29	nw.	27	17	10	4	3.2	.....	....
Grand Rapids	707	70	87	29.24	29.99	+ .01	73.8	+ 1.2	95	22	84	53	29	64	29	65	60	63	1.18	− 1.4	5	3,326	w.	21	w.	17	12	14	5	4.3	.....	....
Houghton	684	62	72	29.26	29.98	+ .02	66.4	+ 1.1	90	6	77	48	8	56	36	....	....	....	3.00	− 0.1	9	5,301	se.	34	n.	26	21	4	6	3.3	.....	....
Lansing	878	11	62	29.07	29.99	......	71.0	− 0.1	95	22	83	46	30	59	35	65	61	74	1.65	− 1.6	5	2,585	ne.	18	se.	13	13	12	6	4.4	.....	....
Ludington	637	60	66	29.32	30.00	......	67.5	......	86	22	75	50	2	60	22	63	60	76	4.40	......	7	5,181	s.	28	n.	12	17	9	5	3.7	.....	....
Marquette	734	77	111	29.22	30.02	+ .06	66.4	+ 1.5	94	6	76	45	18	57	36	60	57	75	3.45	+ 0.4	11	5,194	e.	36	nw.	26	12	10	9	4.9	.....	....
Port Huron	638	70	120	29.31	30.00	+ .02	69.2	+ 0.2	90	26	78	50	19	60	32	63	60	76	2.36	− 0.4	8	5,787	ne.	36	nw.	13	13	12	6	4.4	.....	....
Saginaw	641	48	82	29.32	30.01	......	70.8	......	95	22	81	50	29	60	31	65	62	74	3.40	− 0.3	8	4,226	nw.	22	w.	17	13	10	8	4.5	.....	....
Sault Sainte Marie	614	11	61	29.33	30.02	+ .05	65.2	+ 3.3	88	16	76	45	19	54	33	59	56	74	1.46	− 1.3	7	4,762	w.	27	nw.	18	12	13	6	4.6	.....	....
Chicago	823	140	310	29.14	30.01	+ .03	75.0	+ 2.6	99	23	81	59	19	69	28	67	62	69	2.11	− 1.5	5	6,859	ne.	39	sw.	16	15	16	0	3.2	.....	....
Green Bay	617	109	144	29.33	29.98	+ .01	72.4	+ 2.9	92	21	82	53	18	63	26	66	63	74	4.95	+ 1.4	11	6,700	s.	46	ne.	27	9	13	9	5.6	.....	....
Milwaukee	681	119	133	29.28	30.01	+ .04	72.1	+ 2.4	93	22	80	58	9	65	25	65	61	71	1.03	− 2.0	7	5,510	se.	25	nw.	27	14	14	3	3.9	.....	....
Duluth	1,133	11	47	28.80	30.00	+ .05	65.4	− 0.6	87	25	75	45	18	56	31	62	60	84	2.99	− 0.7	8	6,940	ne.	40	nw.	25	11	15	5	4.4	.....	....
North Dakota.							**72.8**	**+ 3.8**										**68**	**2.41**	**− 0.5**										**3.0**		
Moorhead	940	8	57	28.98	29.97	+ .03	73.1	+ 4.4	95	27	85	51	23	61	36	67	64	75	3.65	− 0.1	9	5,069	se.	28	nw.	25	27	2	2	1.5	.....	....
Bismarck	1,674	8	57	28.22	29.97	+ .04	73.3	+ 3.1	98	26	86	49	19	60	37	64	60	67	2.04	− 0.1	10	6,358	se.	39	sw.	26	22	6	3	2.7	.....	....
Devils Lake	1,482	11	44	28.38	29.92	− .01	71.8	+ 3.7	96	27	84	48	17	60	33	64	60	69	1.63	− 2.2	7	6,778	s.	34	w.	16	17	10	4	3.7	.....	....
Williston	1,872	40	47	27.97	29.90	− .02	73.2	+ 3.8	98	27	87	46	17	60	40	62	57	61	2.32	+ 0.3	6	4,798	se.	39	nw.	15	13	14	4	4.0	.....	....
Upper Mississippi Valley.							**78.3**	**+ 2.9**										**63**	**1.33**	**− 2.3**										**4.1**		
Minneapolis	918	10	208	......	......	......	75.1	......	96	26	85	54	18	66	28	....	....	....	1.17	− 2.6	5	6,972	s.	27	w.	12	14	10	7	4.4	.....	....
St. Paul	837	201	236	29.09	29.97	+ .02	74.6	+ 2.5	95	26	84	53	18	65	30	66	62	66	0.95	− 2.4	4	7,112	se.	36	nw.	12	14	15	2	4.0	.....	....
La Crosse	714	11	48	29.24	29.99	+ .03	74.8	+ 2.2	93	11	84	55	18	65	27	....	....	....	2.39	− 1.7	8	2,980	s.	24	s.	12	10	13	8	4.8	.....	....
Madison	974	70	78	28.99	30.01	+ .04	73.8	+ 1.4	92	11	83	55	30	65	26	66	62	68	1.49	− 2.5	8	5,027	sw.	32	ne.	27	13	13	5	4.7	.....	....
Charles City	1,015	10	49	28.95	30.00	+ .04	74.8	+ 1.3	98	11	87	49	18	63	33	68	64	72	2.30	− 1.3	3	3,552	se.	20	ne.	27	19	11	1	3.5	.....	....
Davenport	606	71	79	29.34	29.99	+ .02	78.6	+ 3.2	100	11	90	55	18	68	27	68	63	62	0.44	− 3.1	5	4,273	e.	33	n.	16	15	12	4	4.1	.....	....
Des Moines	861	84	97	29.08	29.96	.00	78.6	+ 3.1	101	12	90	56	18	68	29	68	64	64	1.22	− 2.6	4	3,992	e.	27	nw.	16	12	14	5	4.3	.....	....
Dubuque	698	81	96	29.28	30.01	+ .04	76.4	+ 1.7	97	11	86	56	18	66	28	68	63	67	1.57	− 2.7	6	3,691	s.	26	n.	16	15	13	3	4.0	.....	....
Keokuk	614	64	78	29.34	30.00	+ .02	80.4	+ 3.4	102	11	92	59	18	69	29	70	65	64	2.09	− 1.9	9	4,123	ne.	29	n.	16	14	17	0	3.5	.....	....
Cairo	356	87	93	29.60	29.97	− .03	83.2	+ 4.6	101	12	93	64	19	73	28	70	65	60	0.35	− 3.1	3	4,680	s.	28	ne.	10	14	10	7	4.5	.....	....
Peoria	609	11	45	29.35	30.01	+ .03	78.8	+ 3.4	102	23	91	54	19	66	36	67	62	62	0.82	− 2.2	4	3,443	ne.	34	w.	16	19	10	2	3.2	.....	....
Springfield, Ill	644	10	91	29.32	29.99	+ .01	81.0	+ 4.5	104	16	93	59	30	70	31	67	61	55	1.39	− 1.5	6	4,457	ne.	32	nw.	16	11	15	5	4.6	.....	....
Hannibal	634	74	109	29.43	29.99	+ .01	80.0	+ 2.6	101	11	91	56	19	69	32	....	....	....	0.87	− 2.9	7	4,850	sw.	35	sw.	16	19	9	3	3.7	.....	....
St. Louis	567	265	303	29.38	29.98	− .01	83.1	+ 4.0	102	11	93	65	30	74	26	69	62	52	1.52	− 1.9	7	6,625	nw.	32	sw.	16	20	8	3	3.8	.....	....
Missouri Valley.							**78.7**	**+ 2.9**										**62**	**2.20**	**−1.6**										**3.9**		
Columbia, Mo	781	11	84	29.18	29.99	+ .01	80.0	+ 2.6	100	16	91	59	20	69	32	....	....	....	1.70	−2.0	8	3,808	s.	24	sw.	16	9	12	10	6.0	.....	....
Kansas City	963	161	181	28.97	29.97	.00	80.8	+ 3.2	101	16	89	62	31	72	26	70	65	62	2.81	−2.0	7	6,994	s.	36	se.	21	12	15	4	4.4	.....	....
St. Joseph	967	11	49	28.97	29.97	......	80.8	......	102	16	91	60	20	70	31	70	65	66	1.38	......	7	4,415	se.	32	nw.	12	16	12	3	3.9	.....	....
Springfield, Mo	1,324	98	104	28.63	30.00	+ .02	78.8	+ 2.4	97	15	86	64	21	71	24	69	64	64	3.35	−1.4	10	5,307	se.	29	nw.	1	16	8	7	4.0	.....	....
Iola	984	11	50	28.95	29.96	+ .01	80.4	+ 2.3	101	15	91	58	2	70	28	....	....	....	3.75	− 0.2	9	3,798	se.	24	n.	31	14	12	5	3.9	.....	....
Topeka	983	85	101	......	......	......	80.2	+ 2.6	102	16	90	62	2	70	32	....	....	....	2.27	− 2.6	8	5,564	s.	50	nw.	16	13	15	3	4.2	.....	....
Lincoln	1,189	11	84	28.73	29.96	+ .01	79.2	+ 2.8	103	12	91	58	18	67	32	68	64	66	4.84	+ 1.0	8	5,517	s.	38	sw.	25	14	13	4	3.8	.....	....
Omaha	1,105	115	121	28.82	29.97	+ .02	79.4	+ 2.9	100	12	89	60	31	70	25	69	64	63	1.09	− 3.2	3	4,615	se.	32	n.	16	18	9	4	3.6	.....	....
Valentine	2,598	47	54	27.33	29.99	+ .06	75.9	+ 2.7	98	9	90	49	17	62	36	63	55	57	1.43	− 2.0	9	6,766	s.	36	sw.	8	23	7	1	2.8	.....	....
Sioux City	1,135	94	164	28.78	29.96	+ .01	77.4	+ 3.2	99	11	88	57	2	66	31	68	63	63	1.16	− 2.4	5	7,204	s.	35	n.	16	14	14	3	3.8	.....	....
Huron	1,306	59	74	28.61	29.97	+ .03	75.8	+ 4.3	101	26	88	52	18	63	38	66	60	64	0.96	− 2.0	3	7,116	se.	37	nw.	5	22	7	2	2.9	.....	....
Pierce	1,572	70	75	28.34	29.96	+ .03	78.7	+ 3.5	102	26	91	54	19	66	34	65	57	53	1.53	− 0.8	6	6,834	se.	36	nw.	29	19	12	0	3.0	.....	....
Yankton	1,233	49	57	28.67	29.96	+ .02	77.4	+ 2.8	101	11	89	58	17	66	30	....	....	....	1.51	− 2.0	7	4,837	nw.	26	se.	3	13	14	4	4.5	.....	....

TABLE I.—*Climatological data for United States Weather Bureau stations, July, 1914*—Continued.

Districts and stations.	Elevation of instruments.			Pressure in inches.			Temperature of the air, in degrees Fahrenheit.									Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity, per cent.	Precipitation, inches.			Wind					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level, feet.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 or more.	Total movement, miles.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.						
Northern Slope.							**70.5**	**+ 2.4**										**53**	**0.78**	**− 0.8**										**3.9**		
Havre	2,505	11	44	27.32	29.89	− .02	72.0	+ 3.9	99	27	88	42	17	56	44	58	50	55	0.41	− 1.5	5	5,110	w.	43	w.	6	21	8	2	2.9	......	....
Helena	4,110	87	114	25.85	29.96	+ .03	69.5	+ 2.9	93	19	84	48	1	55	37	54	45	49	0.21	− 0.9	8	6,179	s.	44	s.	13	14	13	4	3.8	......	....
Kalispell	2,962	11	34	26.93	29.92	− .01	66.7	+ 2.4	97	30	83	42	21	50	45	54	45	53	0.69	− 0.2	7	3,491	w.	24	sw.	13	19	11	1	3.2	......	....
Miles City	2,371	26	48	27.46	29.94	+ .02	78.1	+ 5.2	104	27	93	50	17	63	44	63	53	49	0.78	− 0.6	6	3,737	s.	30	nw.	14	15	16	0	3.4	......	....
Rapid City	3,259	50	58	26.65	29.98	+ .05	74.2	+ 4.0	98	26	88	53	1	60	40	60	51	49	2.17	− 0.4	9	6,155	w.	42	w.	14	10	17	4	4.2	......	....
Cheyenne	6,088	84	101	24.15	29.99	+ .07	66.6	− 0.8	86	26	79	43	1	54	35	54	47	57	1.30	− 0.7	14	7,190	s.	38	se.	28	4	19	8	6.1	......	....
Lander	5,372	60	68	24.75	29.98	+ .06	69.2	+ 1.2	93	12	86	43	1	53	42	53	42	45	0.50	− 0.4	7	3,852	sw.	36	s.	9	10	20	1	4.9	......	....
Sheridan	3,790	10	47	26.16	29.98	......	70.4	......	96	20	87	42	1	54	47	58	49	52	0.13	......	5	3,820	se.	31	se.	22	20	7	4	3.4	......	....
Yellowstone Park	6,200	11	48	24.02	30.02	+ .10	62.0	+ 0.5	84	12	77	38	17	47	40	50	42	57	0.36	− 0.8	6	5,461	s.	34	nw.	24	13	13	5	4.2	......	....
North Platte	2,821	11	51	27.14	30.00	+ .07	76.0	+ 2.1	100	11	90	49	1	63	34	65	60	66	0.58	− 2.1	6	4,489	s.	27	ne.	16	22	7	2	2.8	......	....
Middle Slope.							**79.1**	**+ 2.3**										**60**	**1.52**	**− 1.4**										**4.5**		
Denver	5,291	129	172	24.85	30.00	+ .09	72.2	+ 0.4	94	8	84	50	22	60	34	58	52	58	1.49	− 0.1	13	5,095	sw.	34	n.	1	5	21	5	5.2	......	....
Pueblo	4,685	80	86	25.39	29.98	+ .07	73.2	− 1.0	93	14	86	49	1	61	34	60	55	62	3.92	+ 2.0	11	4,373	nw.	34	nw.	12	11	15	5	4.5	......	....
Concordia	1,398	42	50	28.53	29.96	+ .01	82.1	+ 4.0	110	15	95	59	2	70	38	69	64	61	1.13	− 2.5	7	4,385	se.	25	se.	28	2	22	7	5.9	......	....
Dodge	2,509	11	51	27.41	29.94	+ .01	79.3	+ 1.6	102	15	91	57	8	67	32	67	62	63	0.36	− 3.0	7	5,751	s.	29	ne.	16	16	12	3	3.7	......	....
Wichita	1,358	139	158	28.54	29.93	− .03	82.4	+ 3.4	103	15	92	62	19	72	27	69	64	61	1.60	− 2.0	7	7,872	s.	36	s.	28	19	6	6	3.8	......	....
Oklahoma	1,214	10	47	28.70	29.95	− .01	85.2	+ 5.4	106	31	97	66	2	73	31	70	64	57	0.62	− 3.0	5	8,162	s.	34	nw.	17	14	15	2	4.1	......	....
Southern Slope.							**80.8**	**+ 0.4**										**60**	**3.06**	**+ 0.2**										**3.3**		
Abilene	1,738	10	52	28.19	29.94	+ .01	84.0	+ 1.8	104	31	96	68	23	72	30	69	61	54	1.05	− 1.4	5	6,117	s.	34	e.	23	14	13	4	3.7	......	....
Amarillo	3,676	10	49	26.33	29.98	+ .06	77.8	+ 1.7	97	31	90	60	2	66	30	65	60	64	3.07	− 0.1	8	6,023	s.	40	sw.	20	19	12	0	3.5	......	....
Del Rio	944	64	71	28.96	29.93	+ .03	84.2	− 0.5	99	31	95	67	2	74	28	....	....	....	6.17	+ 3.9	3	6,059	se.	30	se.	2	26	5	0	1.9	......	....
Roswell	3,566	75	85	26.40	29.94	+ .06	77.4	− 1.5	94	31	89	61	2	66	30	64	58	62	1.97	− 1.5	7	4,735	s.	34	se.	28	13	16	2	4.2	......	....
Southern Plateau.							**77.1**	**− 1.9**										**50**	**1.85**	**− 0.6**										**4.3**		
El Paso	3,762	110	133	26.22	29.89	+ .05	78.0	− 2.5	95	31	89	64	17	67	27	64	58	59	4.91	+ 2.8	16	6,645	e.	39	s.	23	12	16	3	4.4	......	....
Santa Fe	7,013	57	62	23.40	29.93	+ .05	67.0	− 1.7	86	31	77	53	24	57	26	56	51	64	3.98	+ 1.3	17	4,326	se.	34	s.	17	1	23	7	6.1	......	....
Flagstaff	6,908	8	57	......	......	......	62.7	− 2.3	83	7	74	41	22	51	38	....	....	....	4.48	......	20	......	nw.	31	s.	12	1	18	12	6.6	......	....
Phoenix	1,108	76	81	28.70	29.81	+ .03	88.8	− 1.6	108	8	100	72	16	77	32	69	58	40	0.21	− 0.9	6	4,139	e.	34	ne.	29	13	13	5	4.5	......	....
Yuma	141	9	58	29.65	29.79	+ .03	91.6	+ 0.7	112	7	107	70	5	77	41	72	64	46	T.	− 0.1	0	4,239	sw.	30	n.	15	28	3	0	0.9	......	....
Independence	3,910	11	42	25.99	29.90	+ .07	74.4	− 4.1	96	1	90	53	28	58	39	57	45	42	0.16	0.0	3	4,400	se.	32	se.	12	18	12	1	3.1	......	....
Middle Plateau.							**71.4**	**− 0.7**										**46**	**1.05**	**+ 0.4**										**4.4**		
Reno	4,532	74	81	25.51	29.92	+ .05	70.6	+ 3.1	94	31	88	49	4	53	41	51	37	37	T.	− 0.1	0	5,198	w.	31	w.	20	25	5	1	2.1	......	....
Tonopah	6,090	12	20	24.14	29.93	......	72.0	......	90	1	83	48	21	61	27	52	34	31	0.59	+ 0.3	7	6,449	se.	30	nw.	20	16	13	2	4.3	......	....
Winnemucca	4,344	18	56	25.63	29.94	+ .04	72.0	+ 0.4	96	19	90	46	9	54	46	52	37	36	0.19	0.0	3	3,889	sw.	26	s.	27	18	12	1	3.0	......	....
Modena	5,479	10	43	24.70	29.94	+ .08	69.0	− 0.7	90	8	83	45	22	55	40	54	44	52	1.50	+ 0.2	10	6,889	sw.	43	s.	21	9	13	9	5.6	T.	....
Salt Lake City	4,360	147	189	25.66	29.94	+ .04	75.2	− 1.0	96	8	86	56	23	64	31	60	52	50	1.20	+ 0.7	8	5,147	se.	39	nw.	20	10	14	7	4.9	......	....
Durango	6,546	18	56	23.79	29.97	+ .08	66.5	− 2.2	90	12	81	45	23	52	40	55	51	69	3.03	+ 1.5	16	3,429	nw.	24	ne.	25	6	17	8	5.5	......	....
Grand Junction	4,602	82	96	25.44	29.97	+ .08	75.4	− 3.8	95	8	87	57	22	64	32	59	51	49	0.86	+ 0.4	12	5,350	se.	40	se.	3	11	12	8	5.1	......	....
Northern Plateau.							**73.7**	**+ 2.8**										**42**	**0.89**	**+ 0.4**										**3.3**	......	....
Baker	3,471	48	53	26.48	29.99	+ .04	68.0	+ 3.0	96	30	84	37	21	52	40	53	42	47	0.71	+ 0.3	3	4,497	nw.	23	sw.	4	19	12	0	2.6	......	....
Boise	2,739	78	86	27.14	29.93	.00	75.2	+ 2.4	98	19	90	43	21	60	37	57	43	39	1.04	+ 0.9	4	3,984	nw.	32	se.	11	18	7	6	3.3	......	....
Lewiston	757	40	48	29.14	29.93	− .02	77.8	+ 4.2	106	30	94	49	21	62	42	....	....	....	0.43	0.0	3	2,918	e.	26	nw.	20	16	14	1	2.9	......	....
Pocatello	4,477	46	54	25.52	29.94	+ .02	71.6	+ 0.4	93	19	86	47	22	58	38	55	44	45	1.78	+ 1.2	11	5,344	se.	33	s.	24	9	15	7	5.0	......	....
Spokane	1,929	101	110	27.94	29.94	− .02	72.6	+ 3.8	99	30	87	48	21	58	42	56	43	42	1.28	+ 0.6	4	4,307	sw.	31	sw.	13	18	10	3	3.2	......	....
Walla Walla	1,000	57	65	28.89	29.94	− .03	77.2	+ 3.1	100	30	91	53	21	64	36	58	44	35	0.12	− 0.3	2	3,271	s.	18	sw.	20	20	9	2	2.9	......	....
North Pacific Coast Region.							**61.5**	**− 0.3**										**72**	**0.07**	**− 0.7**										**3.6**		
North Head	211	11	56	29.90	30.13	+ .05	55.3	− 2.4	62	26	58	49	6	53	8	53	52	88	0.07	− 0.5	2	13,054	nw.	42	nw.	15	15	11	5	4.1	......	....
Port Crescent	259	8	53	29.85	30.14	+ .08	54.4	− 1.9	76	17	63	46	28	46	30	....	....	....	0.03	− 0.6	2	3,791	nw.	15	nw.	19	9	19	3	4.5	......	....
Seattle	125	215	250	29.96	30.09	+ .05	64.2	+ 0.7	88	18	74	49	6	54	29	57	52	69	0.01	− 0.7	1	5,737	ne.	26	n.	19	16	9	6	3.6	......	....
Tacoma	213	113	120	29.86	30.09	+ .03	63.8	+ 0.4	90	18	74	48	28	53	32	56	49	64	0.01	− 0.6	1	4,411	n.	19	sw.	20	16	10	5	3.8	......	....
Tatoosh Island	109	7	57	30.02	30.11	+ .06	54.6	− 0.5	63	17	58	48	27	51	13	53	52	93	0.32	− 1.5	5	6,965	s.	25	s.	14	11	11	9	5.0	......	....
Portland, Oreg.	153	68	106	29.88	30.04	− .01	68.6	+ 2.3	94	18	80	50	21	57	31	58	51	59	0.01	− 0.5	1	5,021	n.	22	n.	19	19	8	4	3.3	......	....
Roseburg	510	9	57	29.48	30.02	− .01	69.6	+ 3.5	102	17	86	46	21	53	46	57	49	58	0.01	− 0.3	1	2,877	n.	18	n.	15	28	3	0	1.2	......	....
Middle Pacific Coast Region.							**64.2**	**− 1.3**										**64**	**0.00**	**0.0**										**4.0**		
Eureka	62	73	89	29.99	30.06	+ .01	54.1	− 1.2	63	15	58	46	27	50	12	52	50	89	0.01	− 0.1	1	4,462	nw.	25	sw.	16	4	10	17	7.0	......	....
Mount Tamalpais	2,375	11	18	27.54	29.98	+ .03	67.6	− 2.9	86	15	74	46	21	61	24	55	44	46	T.	0.0	0	8,781	nw.	50	nw.	7	25	5	1	1.6	......	....
Point Reyes Light	490	7	18	29.45	29.97	......	53.8	+ 0.1	66	14	57	48	9	50	16	....	....	....	0.07	......	4	14,932	nw.	48	nw.	9	1	6	24	8.7	......	....
Red Bluff	332	50	56	29.53	29.87	− .02	80.2	− 1.9	105	16	95	58	12	65	38	61	47	38	T.	0.0	0	3,214	se.	18	n.	16	27	4	0	1.1	......	....
Sacramento	69	106	117	29.83	29.90	+ .02	71.0	− 1.5	102	15	86	52	23	56	42	60	52	60	0.00	0.0	0	5,900	s.	23	s.	11	30	1	0	0.7	......	....
San Francisco	155	200	204	29.82	29.98	+ .03	57.0	− 0.3	73	14	62	49	8	52	20	53	52	88	0.02	0.0	1	9,212	w.	37	w.	15	5	19	7	5.8	......	....
San Jose	141	12	110	29.83	29.98	......	65.6	− 1.3	92	14	77	48	29	54	42	....	....	....	0.00	0.0	0	4,272	nw.	24	s.	16	24	7	0	2.9	......	....
South Pacific Coast Region.							**69.3**	**− 0.6**										**68**	**0.00**	**0.0**										**3.2**		
Fresno	327	89	98	29.53	29.87	+ .04	80.5	− 1.5	104	24	97	57	13	64	40	60	45	36	T.	0.0	0	6,334	nw.	30	nw.	12	27	2	2	1.2	......	....
Los Angeles	338	159	191	29.59	29.96	+ .06	66.8	− 0.6	81	31	76	56	23	58	24	61	58	80	0.01	0.0	1	3,895	s.	15	s.	10	18	13	0	3.4	......	....
San Diego	87	62	70	29.86	29.95	+ .03	65.8	− 1.1	73	8	70	60	29	62	11	61	59	82	0.00	0.0	0	4,694	nw.	19	nw.	31	14	17	0	3.7	......	....
San Luis Obispo	201	47	54	29.82	30.03	+ .08	64.1	+ 0.9	82	8	76	48	8	53	34	56	52	76	T.	0.0	0	2,443	nw.	12	w.	12	8	22	1	4.5	......	....
West Indies.																																
San Juan	82	8	54	29.97	30.06	+ .07	79.4	......	87	12	84	72	25	75	14				5.70	− 0.7	23	11,352	e.	40	ne.	20	13	15	3	4.4	......	....
Panama.																																
Ancon	92	6	69	......	29.79	......	82.4	......	94	2	91	70	28	74	20	77	75	87	4.32	− 3.4	13	6,024	nw.	23	n.	16	8	11	12	6.4	......	....
Culebra	404	5	62	......	29.82	......	81.3	......	93	6	89	70	28	74	18	76	75	91	5.28	− 3.9	14	6,164	nw.	25	ne.	23	0	13	18	7.9	......	....
Colon	10	5	71	......	29.83	......	82.0	......	88	3	85	74	15	78	10	78	77	86	10.74	− 5.5	20	8,503	n.	26	n.	2	5	15	11	6.5	......	....

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1914, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	23			0.47														.47			
Albany, N. Y.	7			0.99														.15			
Alpena, Mich.	23			0.33														.13			
Amarillo, Tex.	4	1.50 p. m.	2.30 p. m.	0.71	1.55 p. m.	2.08 p. m.	T.	.19	.59	.70											
		4.20 p. m.	6.00 p. m.	1.00	4.30 p. m.	5.08 p. m.	.02	.18	.34	.40	.40	.47	.69	.90	.95						
Anniston, Ala.	11	1.28 p. m.	2.33 p. m.	0.94	1.28 p. m.	2.18 p. m.	.00	.06	.11	.23	.29	.40	.50	.59	.69	.80	.88				
	16	7.55 a. m.	9.15 a. m.	0.84	8.20 a. m.	8.38 a. m.	.06	.36	.50	.65	.72										
	17	2.25 p. m.	3.33 p. m.	0.98	2.58 p. m.	3.18 p. m.	.03	.34	.71	.87	.95										
Asheville, N. C.	14			0.76														.56			
Atlanta, Ga.	4	10.15 a. m.	11.40 a. m.	0.93	10.20 a. m.	10.35 a. m.	.01	.27	.65	.84											
	28	3.45 p. m.	8.40 p. m.	0.74	3.50 p. m.	4.55 p. m.	.01	.07	.35	.43	.46	.56									
Atlantic City, N. J.	25	6.21 p. m.	7.10 p. m.	0.92	6.36 p. m.	6.51 p. m.	.01	.18	.58	.86											
	30	5.15 a. m.	7.54 a. m.	0.97	5.19 a. m.	5.39 a. m.	.01	.35	.52	.77	.83										
Augusta, Ga.	6	9.10 p. m.	10.10 p. m.	1.13	9.23 p. m.	9.46 p. m.	.01	.12	.42	.78	1.04	1.11									
Do.	13	3.15 p. m.	4.49 p. m.	1.62	3.19 p. m.	3.59 p. m.	.01	.18	.35	.60	.99	1.23	1.35	1.48	1.57						
Do.	15	4.00 p. m.	7.15 p. m.	0.84	4.46 p. m.	5.01 p. m.	.09	.27	.46	.63											
Do.	28	4.25 p. m.	8.30 p. m.	0.99	4.27 p. m.	4.56 p. m.	.01	.08	.16	.28	.52	.69	.76								
Baker, Oreg.	4			0.42														.31			
Baltimore, Md.	11	12.05 a. m.	D.N.a. m.	1.10	12.32 a. m.	1.07 a. m.	.05	.06	.11	.18	.39	.60	.82	.97							
Bentonville, Ark.	3	8.50 a. m.	11.50 a. m.	1.95	9.56 a. m.	10.35 a. m.	.08	.06	.35	.55	.78	1.10	1.28	1.47	1.57						
	7	12.55 a. m.	2.35 a. m.	1.19	1.08 a. m.	2.01 a. m.	.01	.11	.26	.41	.51	.70	.81	.84	.89	1.05	1.10	1.17			
Binghamton, N. Y.	9	6.18 p. m.	8.40 p. m.	1.62	6.38 p. m.	7.23 p. m.	.02	.10	.33	.39	.54	.76	.94	1.18	1.42	1.50					
Birmingham, Ala.	2	1.47 p. m.	2.25 p. m.	0.59	1.55 p. m.	2.06 p. m.	.01	.29	.55	.58											
	18	D.N.a. m.	D.N.a. m.	1.10	1.24 a. m.	1.41 a. m.	.03	.13	.42	.70	.81										
Bismarck, N. Dak.	28–29	D.N.p. m.	D.N.a. m.	1.20	3.15 a. m.	3.49 a. m.	.21	.11	.20	.28	.47	.58	.82	.97							
Block Island, R. I.	2	7.45 p. m.	7.15 a. m.	2.30	2.55 a. m.	3.45 a. m.	.53	.10	.21	.26	.31	.36	.43	.50	.58	.69	.87				
Boise, Idaho	4			0.49														.35			
Boston, Mass.	7			0.96														.56			
Buffalo, N. Y.	14			0.45														.40			
Burlington, Vt.	17			0.35														.35			
Cairo, Ill.	10			0.32														.23			
Canton, N. Y.	25			0.54														.52			
Charles City, Iowa	24			1.20														.60			
Charleston, S. C.	3	D.N.a. m.	7.35 a. m.	1.88	4.32 a. m.	5.39 a. m.	.24	.06	.09	.28	.51	.59	.72	.84	.95	1.06	1.12	1.26	1.52		
	4	10.49 a. m.	8.15 p. m.	2.24	10.57 a. m.	11.33 a. m.	.02	.14	.32	.58	.84	.94	1.03	1.08	1.12						
Charlotte, N. C.	6	6.50 p. m.	7.12 p. m.	0.54	6.50 p. m.	7.03 p. m.	.00	.32	.47	.53											
Chattanooga, Tenn.	14	5.28 p. m.	11.52 p. m.	1.43	11.00 p. m.	11.27 p. m.	.68	.06	.22	.43	.56	.70	.73								
	15–16	4.20 p. m.	1.16 a. m.	1.95	10.17 p. m.	10.57 p. m.	.47	.15	.35	.46	.59	.83	.90	.94	1.05						
	28	1.44 p. m.	3.20 p. m.	0.91	1.56 p. m.	2.36 p. m.	.01	.13	.28	.40	.51	.61	.69	.75	.81						
Cheyenne, Wyo.	17			0.45														.45			
Chicago, Ill.	16	1.58 p. m.	3.25 p. m.	1.65	1.58 p. m.	2.32 p. m.	.00	.24	.50	.69	.82	1.13	1.46	1.62							
Cincinnati, Ohio	25	11.00 p. m.	11.40 p. m.	0.66	11.00 p. m.	11.17 p. m.	.00	.10	.37	.62	.66										
Cleveland, Ohio	23			0.44														.38			
Columbia, Mo.	7			0.66														.37			
Columbia, S. C.	6–7	11.24 p. m.	D.N.a. m.	1.35	12.24 a. m.	1.05 a. m.	.11	.07	.10	.13	.30	.56	.78	.93	1.05	1.09					
	9	5.25 p. m.	D.N.p. m.	1.23	5.28 p. m.	5.57 p. m.	.03	.12	.19	.27	.49	.57	.64								
Columbus, Ohio	13			0.76														.53			
Concord, N. H.	11			0.82														*			
Concordia, Kans.	28	3.37 p. m.	5.58 p. m.	0.94	4.44 p. m.	5.16 p. m.	.12	.21	.38	.42	.61	.70	.76	.79							
Corpus Christi, Tex.	12	9.06 a. m.	10.41 a. m.	0.78	9.54 a. m.	10.24 a. m.	.03	.17	.21	.24	.44	.66	.72								
Dallas, Tex.	24			0.50														.46			
Davenport, Iowa	16			0.28														.18			
Dayton, Ohio	13			1.28														.43			
Del Rio, Tex.	1–2	11.50 p. m.	8.20 a. m.	5.37	2.07 a. m.	3.58 a. m.	.17	.08	.18	.36	.56	.84	.99	1.10	1.32	1.45	1.65	2.13	2.93	3.31	3.56
	2				5.08 a. m.	5.31 a. m.	3.76	.27	.47	.61	.75	.79									
Denver, Colo.	22			0.51														.46			
Des Moines, Iowa	16			0.51														.44			
Detroit, Mich.	13			1.48														.66			
Devils Lake, N. Dak.	5	8.40 p. m.	D. N. p. m.	0.93	8.44 p. m.	9.13 p. m.	.01	.16	.36	.45	.57	.64	.69								
Dodge City, Kans.	19.20			0.21														.16			
Dubuque, Iowa	27			0.62														.47			
Duluth, Minn.	11–12	9.10 p. m.	D. N. a. m.	2.41	9.49 p. m.	10.39 p. m.	.06	.06	.10	.13	.26	.46	.49	.57	.65	.80	.95				
					10.39 p. m.	11.29 p. m.		1.07	1.23	1.34	1.45	1.52	1.57	1.61	1.64	1.71	1.85				
					11.29 p. m.	11.56 p. m.		1.92	1.97	2.03	2.06	2.17	2.21								
Durango, Colo.	4			0.97														*			
Eastport, Me.	12			0.57														.24			
Elkins, W. Va.	4	12.42 p. m.	2.54 p. m.	1.07	12.57 p. m.	1.19 p. m.	.01	.17	.48	.78	.98	1.02									
Do.	14–15	7.10 p. m.	D. N. a. m.	2.24	7.16 p. m.	7.39 p. m.	.01	.17	.29	.44	.55	.62									
Do.	25–26	10.45 p. m.	9.30 a. m.	1.60	1.39 a. m.	1.52 a. m.	.41	.24	.44	.56											
Do.	28	D. N. a. m.	D. N. a. m.	0.72	3.35 a. m.	3.53 a. m.	.03	.12	.29	.59	.69										
El Paso, Tex.	16	5.40 p. m.	7.20 p. m.	1.15	6.32 p. m.	7.05 p. m.	.26	.06	.12	.24	.39	.59	.78	.85							
Erie, Pa.	13			0.82														.27			
Escanaba, Mich.	26–27	11.30 p. m.	9.45 a. m.	1.32	6.12 a. m.	6.37 a. m.	.44	.10	.33	.38	.51	.59									
Eureka, Cal.	3			0.01														.01			
Evansville, Ind.	16–17	7.25 p. m.	D. N. a. m.	0.92	1.37 a. m.	1.57 a. m.	.12	.15	.41	.67	.78										
Fort Smith, Ark.	3–4			0.91														*			
Fort Wayne, Ind.	1	4.25 p. m.	5.15 p. m.	0.71	4.35 p. m.	4.54 p. m.	.02	.09	.28	.58	.68										
	13	6.40 p. m.	9.20 p. m.	1.05	6.52 p. m.	7.19 p. m.	.02	.16	.37	.46	.68	.92	.96								
Fort Worth, Tex.	25			0.55														.39			
Fresno, Cal.	16			T.														T.			
Galveston, Tex.	11			0.39														.36			
Grand Haven, Mich.	27			0.59														.56			
Grand Junction, Colo.	13			0.30														.30			
Grand Rapids, Mich.	27			0.55														.47			
Green Bay, Wis.	22	11.30 p. m.	11.55 p. m.	0.63	11.37 p. m.	11.50 p. m.	.01	.11	.47	.62											
	23	12.40 a. m.	5.05 a. m.	0.98	12.48 a. m.	1.02 a. m.	.02	.38	.64	.73											
	27	8.55 a. m.	10.45 a. m.	1.11	9.05 a. m.	9.30 a. m.	.03	.16	.40	.57	.69	.78									
Hannibal, Mo.	31			0.19														.13			
Harrisburg, Pa.	10–11	8.00 p. m.	D. N. a. m.	1.21	8.43 p. m.	9.21 p. m.	.02	.21	.55	.72	.85	.88	.93	1.01	1.07						
Do.	14	4.10 a. m.	2.10 p. m.	1.27	5.57 a. m.	6.27 a. m.	.13	.05	.11	.27	.43	.55	.61								
Do.	15	10.40 a. m.	12.30 p. m.	0.62	10.55 a. m.	11.25 a. m.	.01	.06	.10	.27	.41	.45	.51								
Do.	25	3.20 p. m.	4.05 p. m.	0.74	3.25 p. m.	3.43 p. m.	.01	.10	.22	.62	.73										
Hartford, Conn.	2			1.10														.47			
Hatteras, N. C.	19	11.33 a. m.	1.05 p. m.	0.98	11.53 a. m.	12.16 a. m.	.07	.16	.42	.62	.78	.85									
Havre, Mont.	11			0.13														.13			
Helena, Mont.	20			0.05														.05			
Houghton, Mich.	26	8.45 p. m.	D. N. p. m.	0.56	8.56 p. m.	9.18 p. m.	.01	.11	.23	.25	.45	.50									
Houston, Tex.	9	2.40 p. m.	3.45 p. m.	0.94	2.51 p. m.	3.35 p. m.	.01	.22	.42	.47	.48	.52	.54	.65	.85	.91					
	22	9.11 p. m.	D. N. p. m.	0.58	9.18 p. m.	9.32 p. m.	.01	.20	.47	.54											

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1914, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Huron, S. Dak	30			0.24														.11			
Independence, Cal	20			0.08														.05			
Indianapolis, Ind	1			0.31														.08			
Iola, Kans	4	5.20 a. m.	2.12 p. m.	1.72	11.27 a. m.	12.02 p. m.	.80	.08	.13	.18	.25	.40	.62	.79							
Jacksonville, Fla	20	2.31 p. m.	7.35 p. m.	1.41	2.36 p. m.	3.12 p. m.	.01	.09	.17	.34	.46	.58	.76	.88	.91						
	26	3.20 p. m.	4.50 p. m.	0.81	3.31 p. m.	4.18 p. m.	.02	.14	.26	.34	.41	.47	.53	.60	.64	.69	.72				
Kalispell, Mont	13			0.19														.10			
Kansas City, Mo	6	3.15 a. m.	5.00 a. m.	1.19	3.21 a. m.	3.58 a. m.	.01	.20	.29	.36	.47	.66	.81	1.09	1.15						
		6.25 p. m.	7.05 p. m.	0.67	6.27 p. m.	6.37 p. m.	.01	.35	.58												
Keokuk, Iowa	16–17	10.10 p. m.	12.20 a. m.	0.57	10.13 p. m.	10.31 p. m.	.01	.14	.30	.43	.50										
Key West, Fla	6			0.66														.28			
Knoxville, Tenn	14–15	2.31 p. m.	11.05 a. m.	3.04	2.42 p. m.	3.06 p. m.	.01	.13	.23	.43	.62	.71									
					7.50 a. m.	8.32 a. m.	2.09	.05	.24	.36	.43	.50	.63	.72	.77	.81					
	26	3.40 p. m.	D. N. p. m.	1.83	5.25 p. m.	6.27 p. m.	.37	.07	.21	.30	.33	.33	.34	.38	.48	.74	.93	1.12	1.18		
La Crosse, Wis	12	5.00 a. m.	6.02 a. m.	1.38	5.12 a. m.	5.43 a. m.	.01	.17	.31	.64	.96	1.20	1.34	1.36							
Lander, Wyo	28			0.27														.17			
Lansing, Mich	13	D. N. a. m.	D. N. a. m.	0.61	12.18 a. m.	12.43 a. m.	.01	.13	.17	.19	.36	.58									
Lewiston, Idaho	7			0.18														.18			
Lexington, Ky	15	1.37 p. m.	3.58 p. m.	1.23	1.41 p. m.	2.10 p. m.	.01	.20	.39	.50	.79	1.06	1.14								
Lincoln, Nebr	25	5.20 p. m.	6.37 p. m.	3.12	5.29 p. m.	6.19 p. m.	.02	.29	.72	1.26	1.88	2.18	2.53	2.78	2.90	2.99	3.06				
	30	9.18 p. m.	10.15 p. m.	0.94	9.29 p. m.	10.09 p. m.	.05	.10	.18	.34	.45	.57	.71	.83	.88						
Little Rock, Ark	6	7.00 a. m.	10.00 a. m.	0.86	9.01 a. m.	9.31 a. m.	.16	.06	.16	.28	.48	.61	.66								
	8	D. N. a. m.	9.30 a. m.	1.67	4.24 a. m.	5.42 a. m.	.33	.06	.09	.17	.19	.23	.28	.46	.55.	.58	.64	.80	1.04		
Los Angeles, Cal	16			0.01														.01			
Louisville, Ky	9–10	11.53 p. m.	12.35 a. m.	0.60	11.58 p. m.	12.23 a. m.	.03	.09	.15	.23	.35	.55									
	10	5.22 p. m.	6.31 p. m.	0.72	6.01 p. m.	6.17 p. m.	.01	.19	.46	.65	.70										
Ludington, Mich	12	7.40 p. m.	10.30 p. m.	1.32	8.10 p. m.	8.32 p. m.	.06	.11	.35	.70	93	.98									
Lynchburg, Va	1	5.55 p. m.	7.30 p. m.	0.66	6.08 p. m.	6.28 p. m.	.01	.14	.29	.48	.55										
Macon, Ga	3	12.30 p. m.	1.10 p. m.	1.18	12.30 p. m.	12.57 p. m.	.00	.25	.65	.85	1.03	1.14	1.18								
	28	5.31 p. m.	D. N. p. m.	2.30	5.48 p. m.	7.23 p. m.	.01	.11	.34	.49	.61	.80	1.00	1.12	1.17	1.22	1.25	1.37	1.68	1.93	
Madison, Wis	4			0.54														.42			
Marquette, Mich	22–23	2.10 p. m.	D. N. a. m.	1.33	2.31 p. m.	3.01 p. m.	.02	.06	.09	.22	.50	.78	.90								
Memphis, Tenn	2			0.31														.18			
Meridian, Miss	3–4	7.45 p. m.	6.10 a. m.	2.50	7.49 p. m.	8.46 p. m.	.01	.20	.52	.82	1.02	1.30	1.54	1.77	1.98	2.08	2.13	2.21			
Miami, Fla	13	5.47 a. m.	7.33 a. m.	1.18	5.49 a. m.	6.16 a. m.	.01	.12	.29	.31	.52	.79	.92								
Milwaukee, Wis	23			0.34														.22			
Minneapolis, Minn	30			0.54														.29			
Mobile, Ala	15	7.54 a. m.	1.55 p. m.	2.32	8.09 a. m.	8.34 a. m.	.02	.18	.57	.88	1.15	1.21									
Modena, Utah	21			0.65														.37			
Montgomery, Ala	3–4	5.33 p. m.	D. N. a. m.	1.07	7.39 p. m.	7.51 p. m.	.23	.20	.49	.56											
Moorhead, Minn	15	1.25 a. m.	4.25 a. m.	1.58	1.31 a. m.	2.11 a. m.	.01	.17	.39	.61	.72	.84	.97	1.10	1.21						
Mount Tamalpais, Cal	20			T.														T.			
Mount Weather, Va	1	D. N. p. m.	D. N. p. m.	0.79	10.30 p. m.	11.00 p. m.	.05	.13	.33	.49	.52	.59	.73								
	17	2.03 p. m.	2.47 p. m.	1.69	2.08 p. m.	2.41 p. m.	.01	.17	.32	.49	.63	.85	1.33	1.68							
Nantucket, Mass	2			0.98														.37			
Nashville, Tenn	17	4.10 p. m.	4.35 p. m.	0.55	4.14 p. m.	4.29 p. m.	.01	.24	.39	.53											
New Haven, Conn	7	D. N. a. m.	9.15 a. m.	0.56	5.39 a. m.	5.58 a. m.	.01	.14	.24	.39	.50										
	29	2.28 p. m.	6.00 p. m.	1.75	2.28 p. m.	3.21 p. m.	.00	.22	.44	.51	.63	.74	1.05	1.26	1.37	1.45	1.58				
New Orleans, La	2	8.35 a. m.	10.35 a. m.	1.28	8.41 a. m.	9.31 a. m.	.02	.05	.27	.54	.66	.71	.77	.81	.83	.96	1.14				
Do	3	2.00 p. m.	2.35 p. m.	0.68	2.01 p. m.	2.26 p. m.	.01	.25	.34	.46	.61	.66									
Do	10	8.20 a. m.	12.20 p. m.	2.31	9.26 a. m.	9.45 a. m.	.47	.07	.30	.49	.54										
Do					10.47 a. m.	11.22 a. m.	1.25	.23	.55	.70	.84	89	.96	1.01							
Do	18	6.50 p. m.	D. N. p. m.	1.18	6.50 p. m.	7.10 p. m.	.00	.32	.60	.79	.93										
Do	31	11.50 a. m.	12.55 p. m.	0.84	12.02 p. m.	12.30 p. m.	.01	.17	.33	.46	.57	.71	.78								
New York, N. Y	2			1.38														.61			
Norfolk, Va	15	9.00 p. m.	10.05 p. m.	0.83	9.10 p. m.	9.24 p. m.	.04	.33	.67	.74											
Northfield, Vt	5	11.43 a. m.	1.50 p. m.	1.03	12.13 p. m.	12.27 p. m.	.07	.33	.76	.88											
North Head, Wash	25			0.06														.02			
North Platte, Nebr	22			0.43														.26			
Oklahoma, Okla	2			0.20														.19			
Omaha, Nebr	6	1.10 p. m.	2.25 p. m.	0.66	1.14 p. m.	1.40 p. m.	.01	.07	.18	.31	.48	.54	.58								
Oswego, N. Y	17			0.23														.23			
Palestine, Tex	25			0.17														.17			
Parkersburg, W. Va	26	4.14 p. m.	5.45 p. m.	1.70	4.21 p. m.	5.41 p. m.	.01	.21	.23	.24	.24	.28	.47	.60	.81	1.04	1.20	1.49	1.69		
Pensacola, Fla	24	5.35 a. m.	7.15 a. m.	0.63	5.39 a. m.	6.03 a. m.	.01	.16	.23	.35	.50	.55									
	28	11.35 a. m.	1.30 p. m.	0.78	11.41 a. m.	12.12 p. m.	.01	.10	.20	.33	.40	.50	.55	.58							
Peoria, Ill	16			0.41														.38			
Philadelphia, Pa	1–2	12.57 p. m.	D. N. a. m.	1.87	12.58 a. m.	1.18 a. m.	.71	.20	.41	.87	1.05										
Do	15	1.00 p. m.	3.35 p. m.	0.86	2.00 p. m.	2.14 p. m.	.01	.14	.41	.70											
Do	16	8.30 p. m.	9.10 p. m.	0.58	8.30 p. m.	8.47 p. m.	.00	.24	.38	.47	.53										
Do	27–28	8.45 p. m.	7.25 a. m.	2.16	2.08 a. m.	2.38 a. m.	.56	.12	.20	.27	.34	.45	.50								
Phoenix, Ariz	29			0.05														.05			
Pierre, S. Dak	23			0.60														.59			
Pittsburgh, Pa	24	9.15 p. m.	9.50 p. m.	0.32	9.28 p. m.	9.38 p. m.	.01	.24	.31												
Pocatello, Idaho	13			0.67														.40			
Point Reyes Light, Cal	16			0.03														.01			
Port Huron, Mich	13	3.56 p. m.	6.54 p. m.	0.66	4.39 p. m.	4.59 p. m.	.05	.08	.23	.36	.40										
Portland, Me	21			0.34														.34			
Portland, Oreg	12			0.01														.01			
Providence, R. I	2			1.13														.34			
Pueblo, Colo	17	4.28 p. m.	6.36 p. m.	1.24	5.32 p. m.	6.02 p. m.	.12	.14	.44	.78	.94	1.05	1.11								
Raleigh, N. C	1–2	10.56 p. m.	D. N. a. m.	1.42	11.07 p. m.	11.36 p. m.	.02	.14	.48	.73	.87	.95	1.00								
	2	6.34 p. m.	8.36 p. m.	1.29	6.43 p. m.	7.59 p. m.	.01	.18	.38	.42	.49	.56	.56	.56	.57	.62	.74	.92	1.25		
	5	4.16 a. m.	7.20 a. m.	0.76	4.27 a. m.	4.51 a. m.	.03	.14	.27	.37	.54	.60									
	14	3.45 p. m.	5.06 p. m.	3.03	3.51 p. m.	4.39 p. m.	.01	.22	.56	.86	1.48	2.21	2.57	2.76	2.87	2.94	2.99				
Rapid City, S. Dak	2	1.03 p. m.	1.35 p. m.	0.55	1.03 p. m.	1.28 p. m.	.00	.20	.25	.35	.46	.53									
Reading, Pa	27			0.44														.37			
Red Bluff, Cal	19			T.														T.			
Reno, Nev	22			T.														T.			
Richmond, Va	5			1.11														.55			
Rochester, N. Y	23			0.69														.32			
Roseburg, Oreg	7			0.01														.01			
Roswell, N. Mex	2			1.69														.54			
Sacramento, Cal				‡																	
Saginaw, Mich	13			1.24														.56			
St. Joseph, Mo	6	5.58 p. m.	7.22 p. m.	1.14	6.07 p. m.	6.32 p. m.	.05	.25	.48	.70	.93	1.06									
St. Louis, Mo	28			0.58														.27			
St. Paul, Minn	16			0.25														.21			

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1914, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Salt Lake City, Utah	4			0.44														.26			
San Antonio, Tex	12,31			0.01														.01			
San Diego, Cal	1			(‡)																	
Sand Key, Fla	12	12.05 p. m.	2.05 p. m.	1.04	12.25 p. m.	12.36 p. m.	.03	.27	.68	.71											
Sandusky, Ohio	14			0.85														.45			
San Francisco, Cal	11			0.02														.01			
San Jose, Cal				(‡)																	
San Luis Obispo, Cal	16			T.														T.			
Santa Fe, N. Mex	3			0.54														.44			
Sault Ste. Marie, Mich	27			0.33														.19			
Savannah, Ga	27			0.44														.43			
Scranton, Pa	10	2.05 p. m.	5.20 p. m.	1.14	3.47 p. m.	4.09 p. m.	.43	.15	.27	.45	.57	.64									
Scranton, Pa	25	D. N. a. m.	D. N. a. m.	1.95	4.15 a. m.	5.19 a. m.	.78	.09	.20	.29	.42	.47	.49	.51	.57	.66	.74	.97	1.12		
Seattle, Wash	25			0.01														T.			
Sheridan, Wyo	10			0.03														.02			
Shreveport, La	22			0.22														.22			
Sioux City, Iowa	30			0.70														.18			
Spokane, Wash	13			0.69														.22			
Springfield, Ill	17			0.78														.58			
Springfield, Mo	1			0.77														(*)			
Syracuse, N. Y	17			0.88														.48			
Tacoma, Wash	25			0.01														T.			
Tampa, Fla	10	1.55 p. m.	3.10 p. m.	0.94	2.13 p. m.	2.35 p. m.	.15	.16	.49	.56	.70	.77									
Tampa, Fla	28	8.26 a. m.	10.05 a. m.	0.76	8.29 a. m.	8.46 a. m.	.01	.14	.33	.47	.52										
Tatoosh Island, Wash	25			0.18														.03			
Taylor, Tex	12			0.21														.21			
Terre Haute, Ind	16			0.27														.18			
Thomasville, Ga	7	2.00 a. m.	D.N. a.m.	1.86	2.52 a. m.	3.32 a. m.	.07	.31	.66	.89	1.09	1.30	1.51	1.61	1.68						
Thomasville, Ga	12	5.45 p. m.	7.27 p. m.	1.12	5.51 p. m.	6.31 p. m.	.01	.07	.11	.22	.47	.67	.82	.98	1.05						
Toledo, Ohio	24			0.46														.43			
Tonopah, Nev	18			0.30														.30			
Topeka, Kans	23	3.42 p. m.	4.10 p. m.	0.46	3.54 p. m.	4.05 p. m.	.02	.17	.40	.44											
Trenton, N. J	29			0.57														.49			
Valentine, Nebr	29			0.83														.49			
Vicksburg, Miss	15	2.30 a. m.	5.35 a. m.	2.73	2.53 a. m.	3.52 a. m.	.03	.09	.20	.32	.47	.82	1.25	1.54	1.81	2.09	2.24	2.38			
Walla Walla, Wash	4			0.11														.04			
Washington, D. C	28	3.12 p. m.	3.58 p. m.	0.50	3.15 p. m.	3.29 p. m.	.01	.19	.39	.46											
Wichita, Kans	5			0.41														.41			
Williston, N. Dak	11	3.50 a. m.	5.50 a. m.	1.32	4.16 a. m.	4.43 a. m.	.07	.22	.54	.71	.81	.92	.98								
Williston, N. Dak	28	6.16 p. m.	10.10 p. m.	0.65	6.16 p. m.	6.50 p. m.	.00	.17	.27	.28	.39	.44	.48	.56							
Wilmington, N. C	7	3.40 p. m.	4.35 p. m.	0.97	3.54 p. m.	4.23 p. m.	.01	.23	.50	.60	.73	.83	.93								
Winnemucca, Nev	3			0.17														.12			
Wytheville, Va																		(*)			
Yankton, S. Dak	30			0.87														.57			
Yellowstone Park, Wyo	14			0.11														.07			

*Self-register not working. †Record partly estimated. ‡No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, July, 1914.*

Stations.	Pressure. Station reduced to mean of 24 hours.	Pressure. Sea-level reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature. Mean max. + mean min. ÷2.	Temperature. Departure from normal.	Temperature. Mean maximum.	Temperature. Mean minimum.	Temperature. Highest.	Temperature. Lowest.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Total snowfall.
	Inches.	*Inches.*	*Inches.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F	29.77	29.90	–.07	56.0	–3.3	63.5	48.5	82	39	4.13	+0.24	
Sydney, C. B. I	29.92	29.96	+.03	61.5	–0.8	70.4	52.7	85	41	2.28	–1.37	
Halifax, N. S	29.87	29.97	+.01	61.4	–2.0	70.9	51.8	88	41	4.09	+0.04	
Yarmouth, N. S	29.92	29.99	+.04	59.0	–0.5	65.9	52.1	75	44	1.10	–2.52	
Charlottetown, P. E. I	29.91	29.95	+.05	63.4	–0.7	71.7	55.1	81	39	2.14	–1.35	
Chatham, N. B	29.92	29.94	+.06	65.8	+0.8	77.9	53.7	90	42	2.07	–2.12	
Father Point, Que	29.88	29.90	+.05	58.7	+1.1	68.3	49.1	90	36	2.02	–1.02	
Quebec, Que	29.63	29.95	+.04	66.4	+0.9	77.6	55.3	92	46	1.18	–3.08	
Montreal, Que	29.76	29.96	+.03	68.3	–0.2	77.7	58.8	91	50	0.96	–3.33	
Stonecliffe, Ont	29.38	29.98	+.04	66.0	+0.4	80.3	51.6	92	40	1.52	–1.60	
Ottawa, Ont	29.72	30.04	+.10	67.4	–2.1	77.3	57.5	88	46	2.35	–1.12	
Kingston, Ont	29.68	29.98	+.01	70.5	+2.3	76.8	64.2	86	50	0.98	–1.91	
Toronto, Ont	29.58	29.94	–.03	70.4	+2.4	80.5	60.4	93	48	1.00	–1.92	
White River, Ont												
Port Stanley, Ont	29.36	29.99	+.01	68.9	+1.1	78.4	59.4	89	48	3.36	+0.32	
Southampton, Ont	29.31			65.4	+0.7	73.8	57.0	85	45	1.70	–0.28	
Parry Sound, Ont	29.32	30.00	+.04	67.5	+1.5	79.3	55.7	92	45	1.05	–1.57	
Port Arthur, Ont	29.29	30.00	+.06	63.5	+1.5	74.1	53.5	88	41	2.30	–1.18	
Winnipeg, Man	29.10	29.91	–.02	72.2	+6.2	83.9	60.6	94	47	7.14	+4.06	
Minnedosa, Man	28.14	29.90	–.03	70.6	+8.4	84.6	56.5	99	42	2.23	–0.37	
Qu'Appelle, Sask	27.66	29.86	–.06	69.5	+6.0	82.4	56.6	97	42	4.76	+2.28	
Medicine Hat, Alberta	27.59	29.80	–.10	75.6	+7.8	93.0	58.1	104	46	0.34	–1.75	
Swift Current, Sask	27.33	29.82	–.09	72.5	+6.0	90.5	54.5	101	40	0.76	–1.68	
Calgary, Alberta	26.37	29.81	–.09	66.4	+5.8	82.3	50.6	94	42	2.52	–0.16	
Banff, Alberta	25.42	29.92	+.02	60.8	+4.2	76.8	44.7	90	34	1.11	–2.13	
Edmonton, Alberta	27.60	29.84	–.06	63.5	+2.9	75.2	51.8	85	40	3.24	+0.21	
Prince Albert, Sask	28.31	29.84	–.07	67.0	+5.1	78.2	55.9	93	45	1.15	–0.90	
Battleford, Sask	28.13	29.82	–.08	69.5	+4.8	83.5	55.5	96	47	1.28	–1.06	
Kamloops, B. C	28.72	29.96	+.02	70.9	+2.4	85.0	56.9	95	44	0.53	–1.08	
Victoria, B. C	29.83	29.97	–.08	59.7	–0.3	67.5	51.8	80	48	T.	–0.40	
Barkerville, B. C	25.75	30.04	+.17	52.1	–3.0	63.5	40.6	74	32	4.69	+1.67	
Hamilton, Bermuda	30.03	30.19	+.05	77.8	–0.9	83.0	72.7	87	69	1.64	–2.80	

Chart I. Hydrographs of Several Principal Rivers, July, 1914.

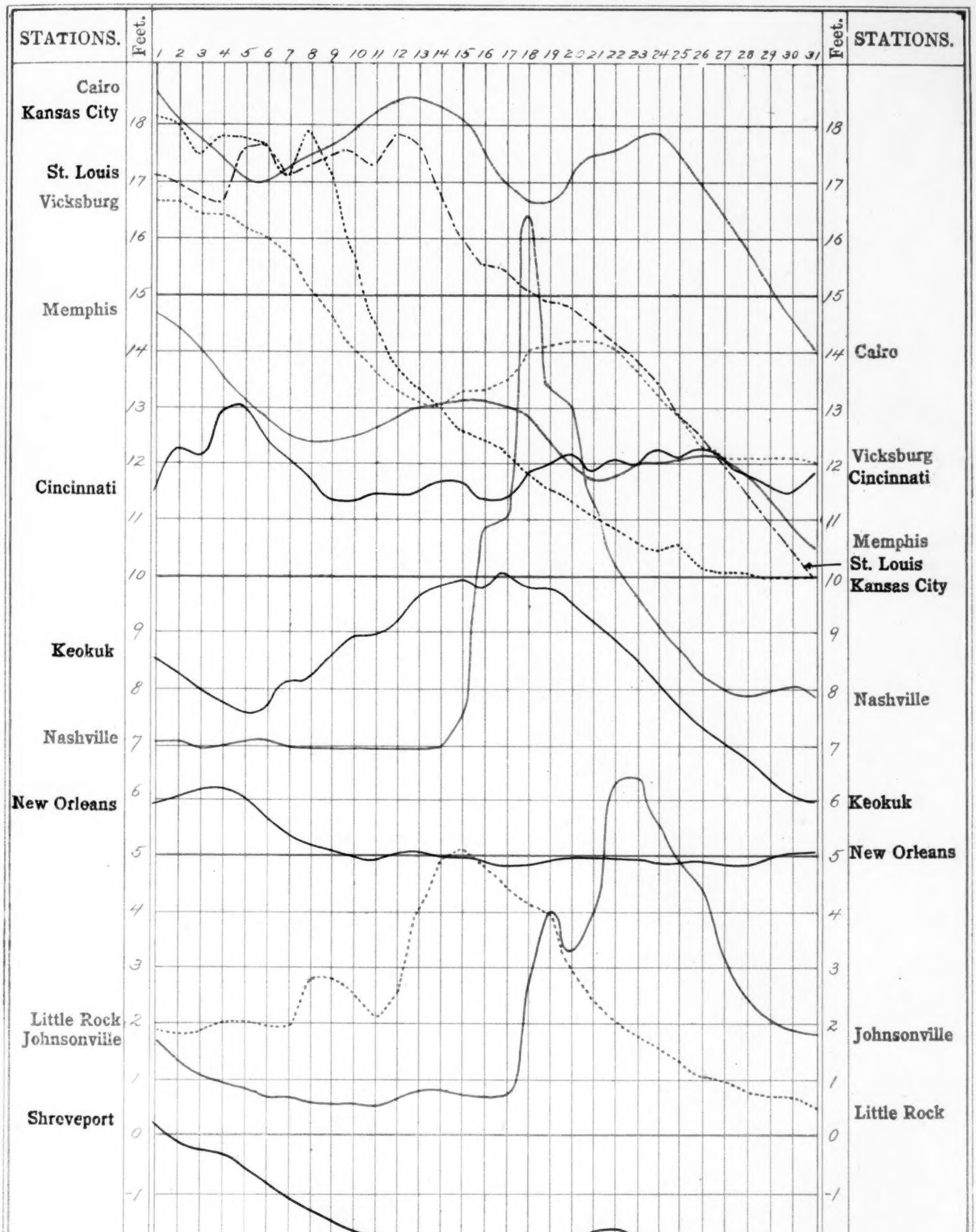

Chart II. Tracks of Centers of High Areas, July, 1914.

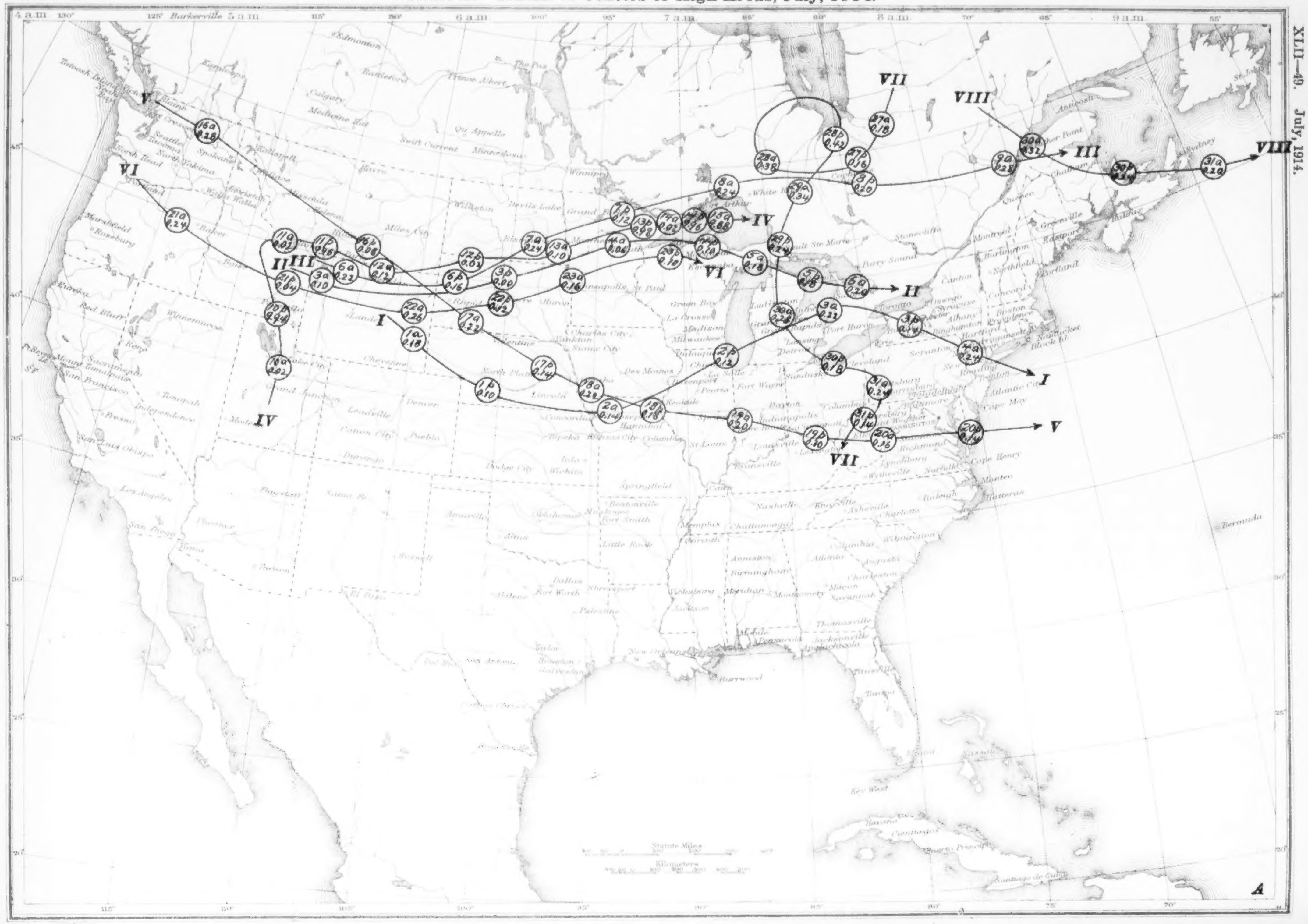

Chart III. Tracks of Centers of Low Areas, July, 1914.

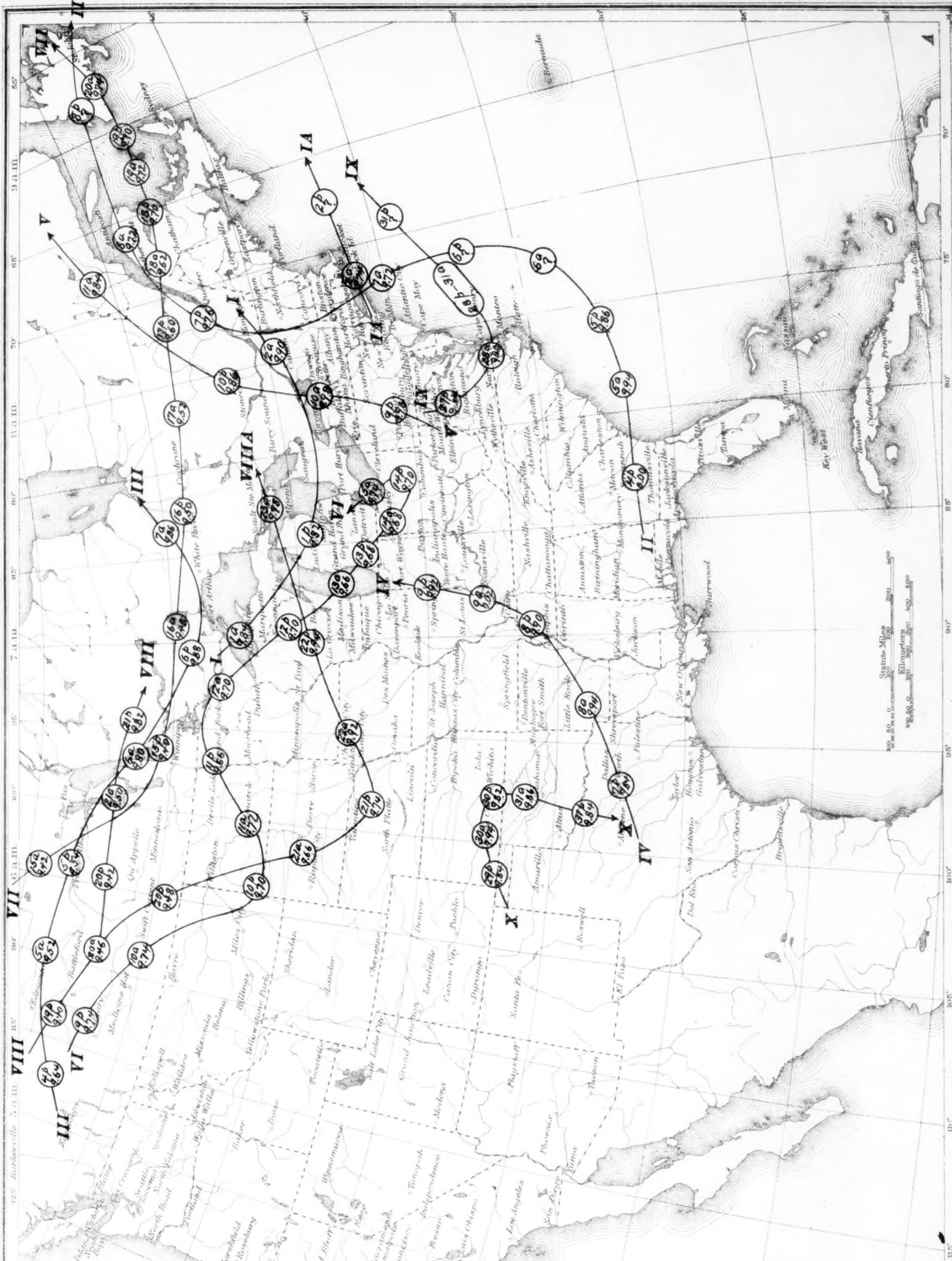

Chart IV. Departure of the Mean Temperature from the Normal, July, 1914.

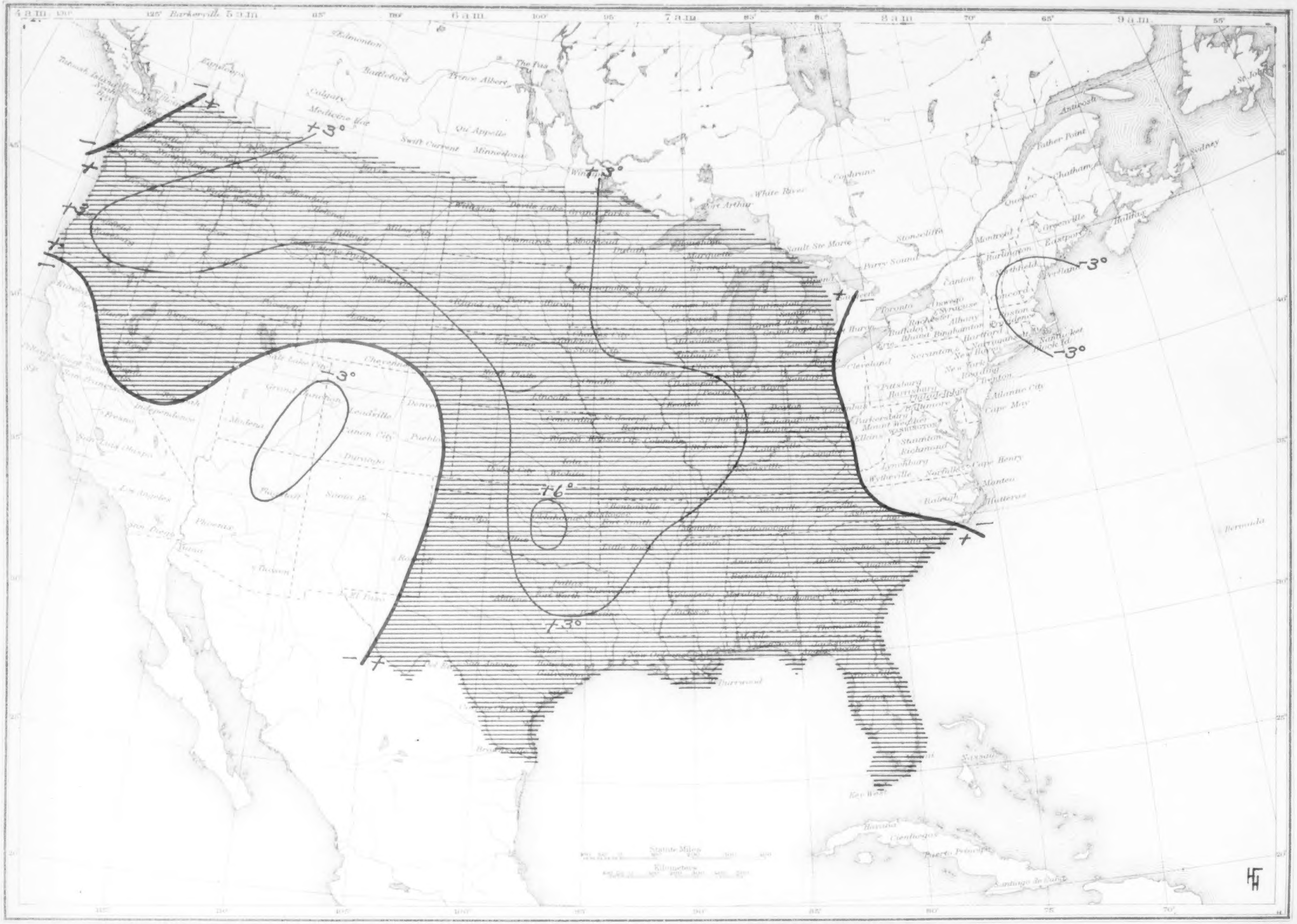

Chart V. Total Precipitation, inches, July, 1914.

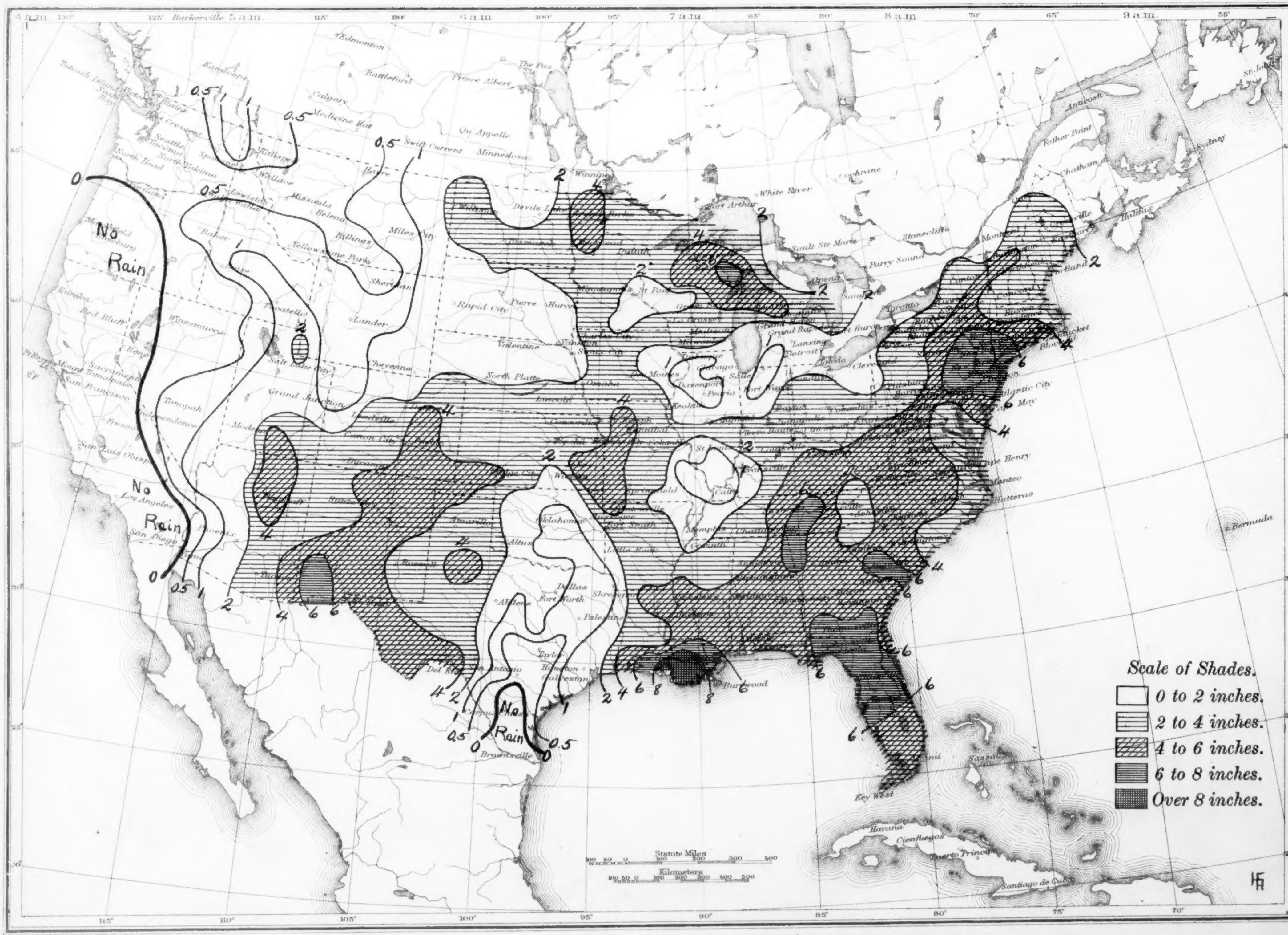

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, July, 1914.

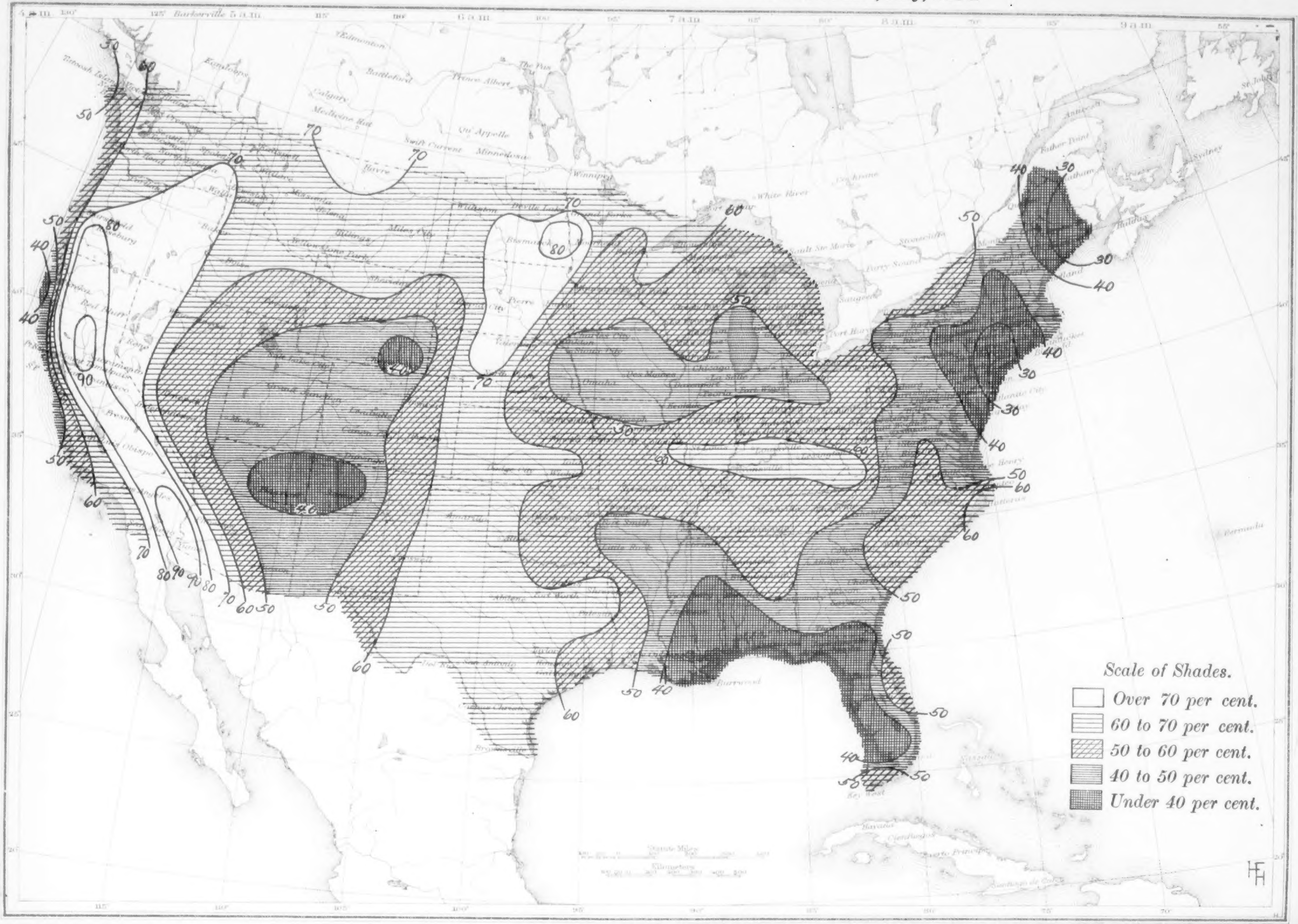

Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, July, 1914.